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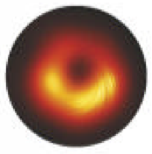

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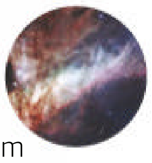

Tour the Milky Way
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Have you ever wanted to know everything about the universe? This month, **All About Space** has the full guide to our cosmos, from its birth in the Big Bang and the objects within it to how we suspect it's going to end - turn to page 14 for our complete guide.

The evenings might be lighter, but if you wait long enough until it gets dark, now is the perfect time to explore our very own galaxy - the Milky Way - with the naked eye, binoculars or a telescope. There are plenty of targets within its dusty path across the night sky, so we've provided guides beyond the summer and into autumn and winter to offer you the very best advice on capturing the most stunning gems of the galaxy. I'll be joining you, so happy hunting!

Elsewhere in the issue, if you're a fan of exoplanets of the extreme variety, then you're in luck: we get up close to the worlds with the strangest weather, crazy temperature swings and other astonishing characteristics. If you have your smartphone or tablet to hand, you can also scan the codes to see three-dimensional, augmented reality models of these alien worlds. I hope you enjoy the experience!

I couldn't end this editorial without mentioning that our Research Editor, Baljeet Panesar, will be moving on after years working on the magazine. We wish her all the best for the future!

GEMMA LAVENDER
EDITOR-IN-CHIEF

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6 JULY 2021

Opening night for CONCERTO

This stunning portrait of NGC 6334, also known as the Cat's Paw Nebula, is one of the first images taken by the CONCERTO instrument on the European Southern Observatory's (ESO) Atacama Pathfinder Experiment (APEX). The white and pink tones have been combined with an image of the same region taken by the ESO's Visible and Infrared Survey Telescope for Astronomy (VISTA) in near-infrared light. CONCERTO is designed to study cosmic bodies that formed between 600 million and 1.2 billion years after the Big Bang to aid our understanding of the first generation of stars.

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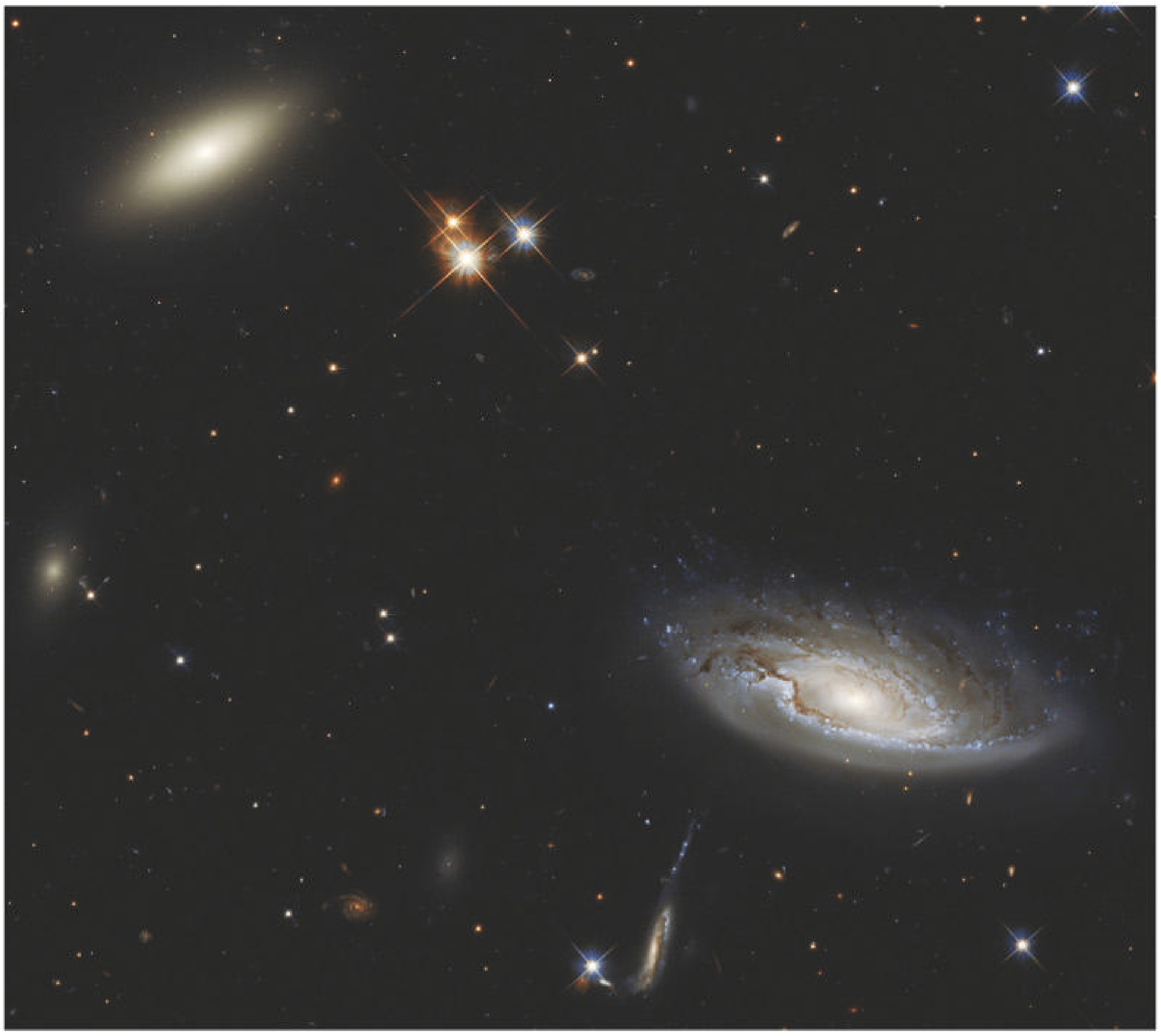

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9 JULY 2021

Galactic giants

This impressive image, taken with Hubble's Wide Field Camera 3, has captured two enormous galaxies nestled within the huge Perseus Cluster approximately 350 million light years away. On the left-hand side of the image is a lenticular galaxy – an intermediate between elliptical and spiral galaxies – named 2MASX J03193743+4137580, and on the right-hand side of the image is the more 'catchily' named spiral galaxy UGC 2665, viewed side on. The Perseus Cluster is one of the largest objects in the known universe. The gigantic cluster contains thousands of galaxies, a handful of which are visible in this image.

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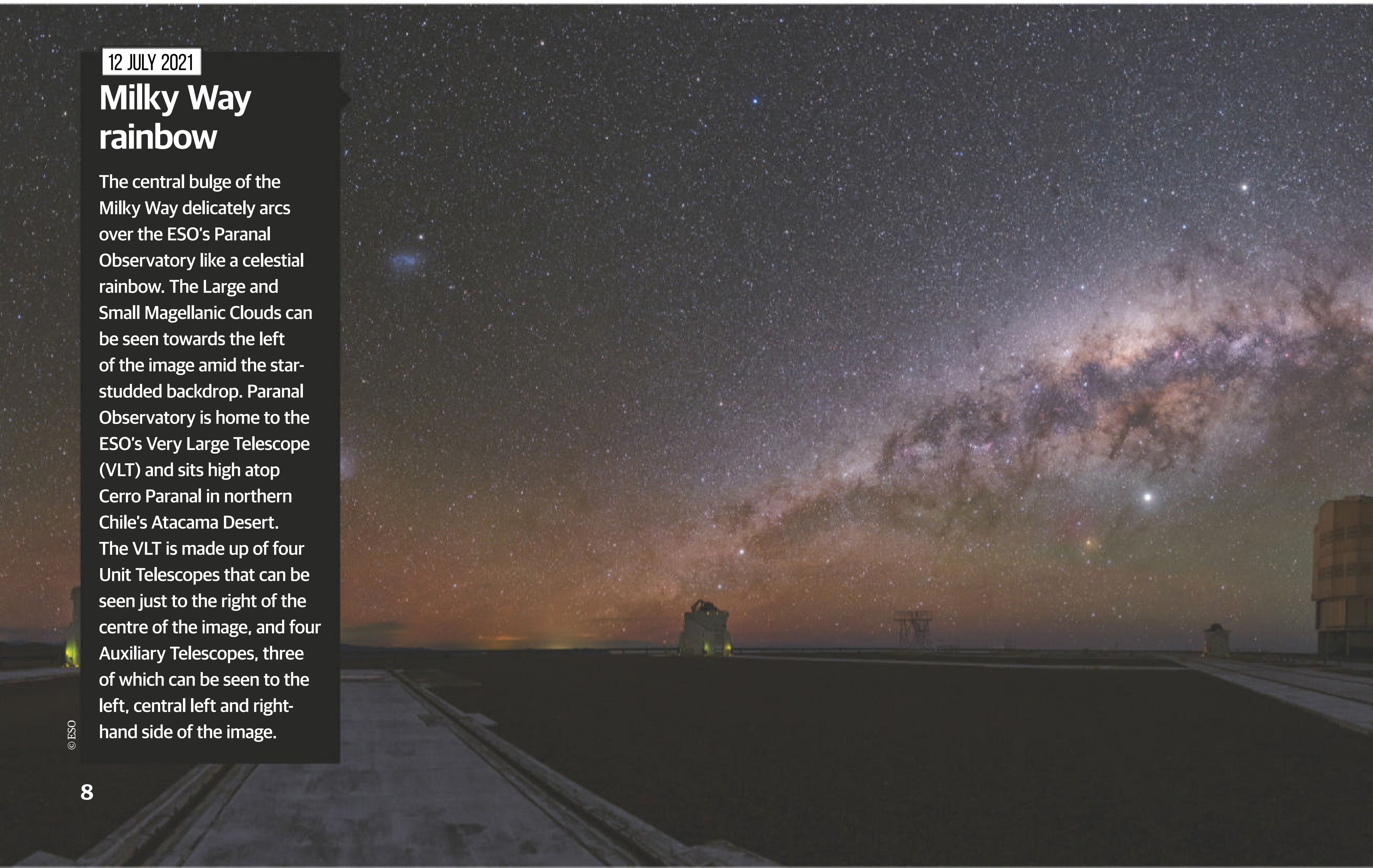

12 JULY 2021

Milky Way rainbow

The central bulge of the Milky Way delicately arcs over the ESO's Paranal Observatory like a celestial rainbow. The Large and Small Magellanic Clouds can be seen towards the left of the image amid the star-studded backdrop. Paranal Observatory is home to the ESO's Very Large Telescope (VLT) and sits high atop Cerro Paranal in northern Chile's Atacama Desert. The VLT is made up of four Unit Telescopes that can be seen just to the right of the centre of the image, and four Auxiliary Telescopes, three of which can be seen to the left, central left and right-hand side of the image.

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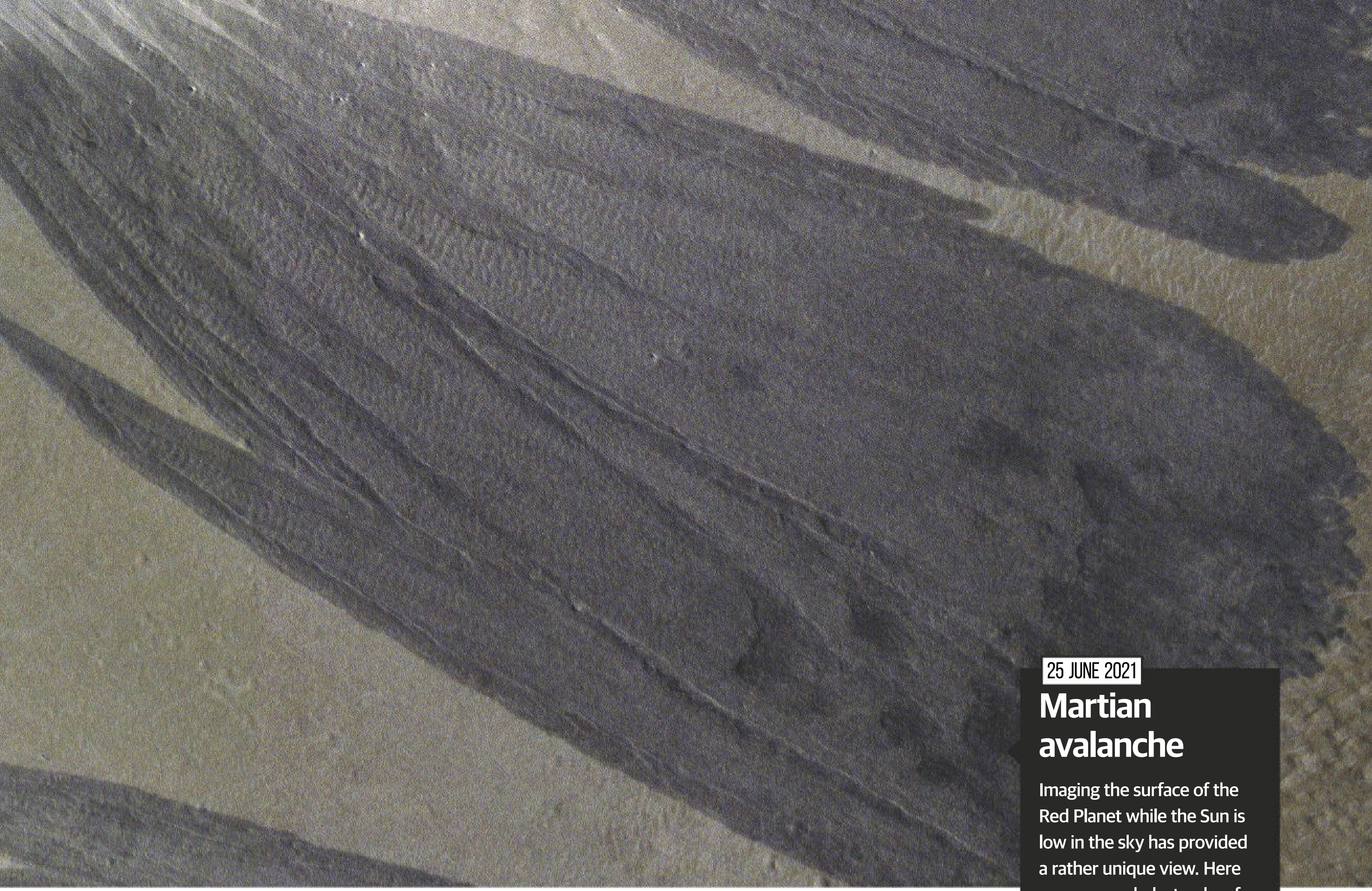


25 JUNE 2021

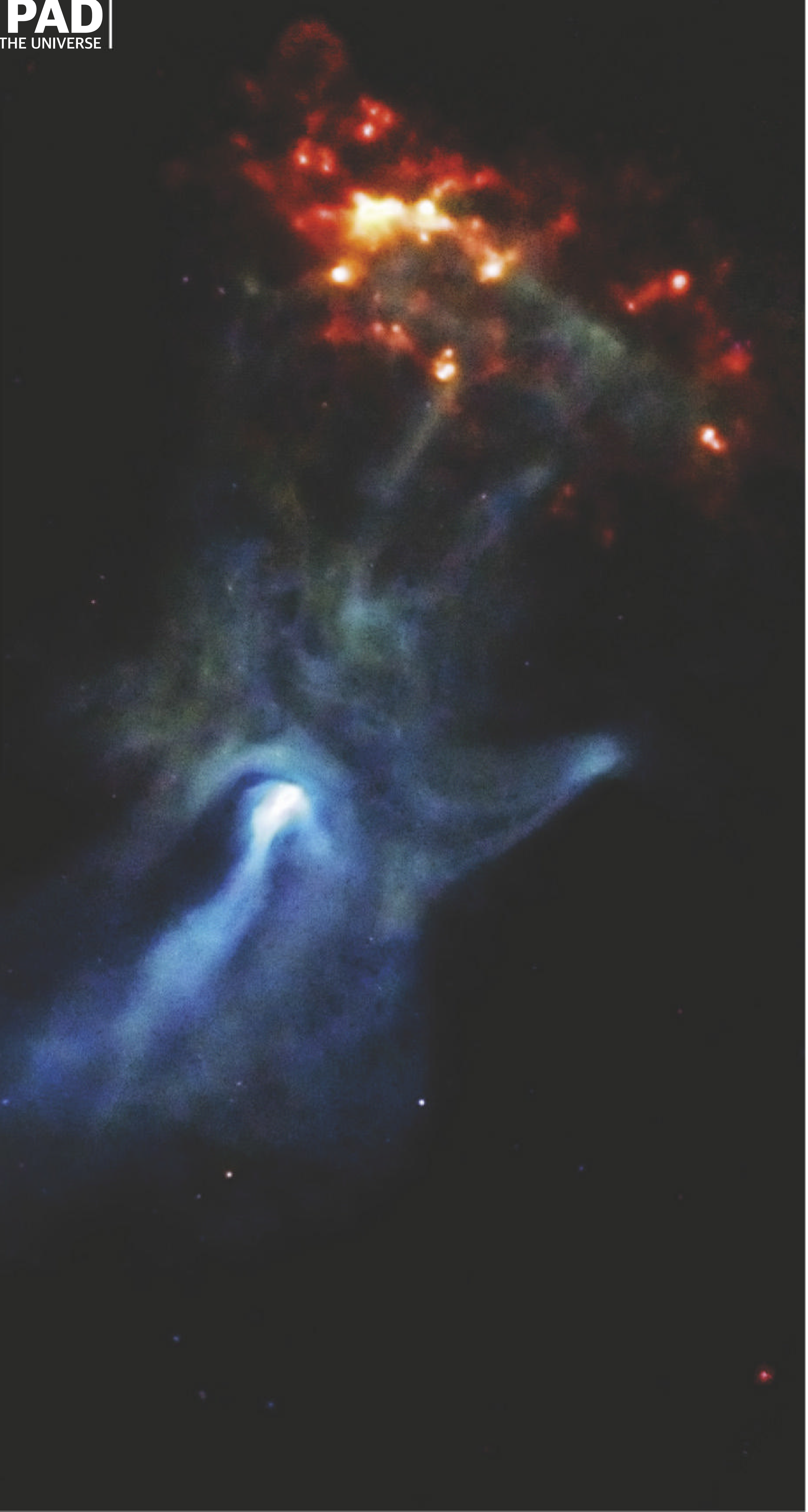
Martian avalanche

Imaging the surface of the Red Planet while the Sun is low in the sky has provided a rather unique view. Here we can see dark streaks of material that have shifted from slopes and deposited in lobes. The topographic signature is typical of landslides, also known as mass movements. These are much more common during spring and summer, and one theory is that the thawing of ice destabilises the frozen surface, causing this mass movement. The High Resolution Imaging Experiment (HiRISE) on the Mars Reconnaissance Orbiter captured this scene.

24 JUNE 2021

A ghostly grasp

This ghostly scene was captured by NASA's Chandra X-ray Observatory, showing an eerie 'hand' reaching out and grasping onto a giant gas cloud called RCW 89. The 'hand' was forged by a supernova that left behind a dense pulsar, which has since spawned a large bubble of energetic particles around itself. The blast wave and surrounding material from the explosion are now colliding with the gas cloud RCW 89. The supernova remnant MSH 15-52 is located approximately 17,000 light years from Earth and is one of the youngest supernova remnants in our galaxy. Light from the supernova explosion is thought to have reached Earth just 1,700 years ago.



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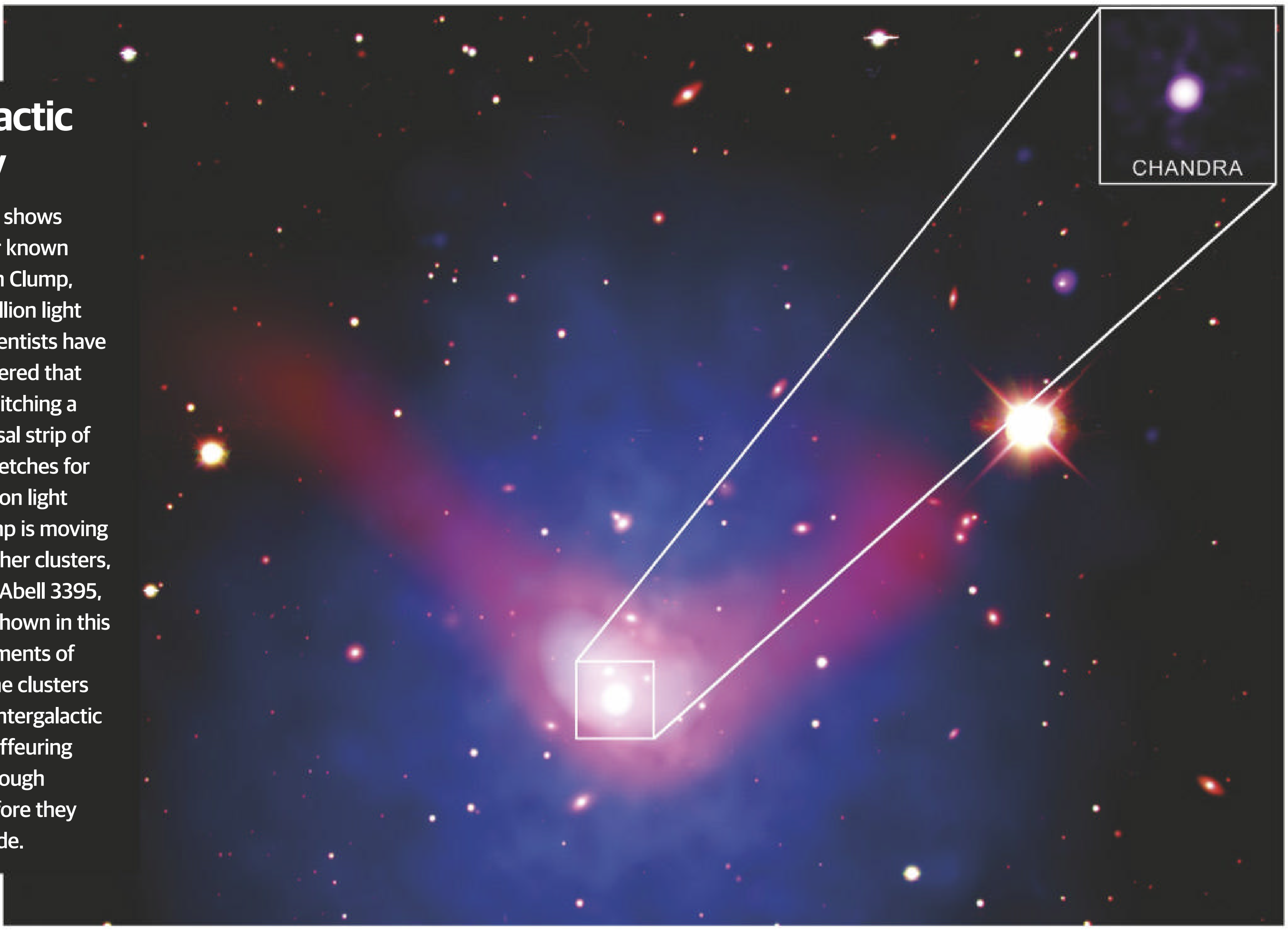

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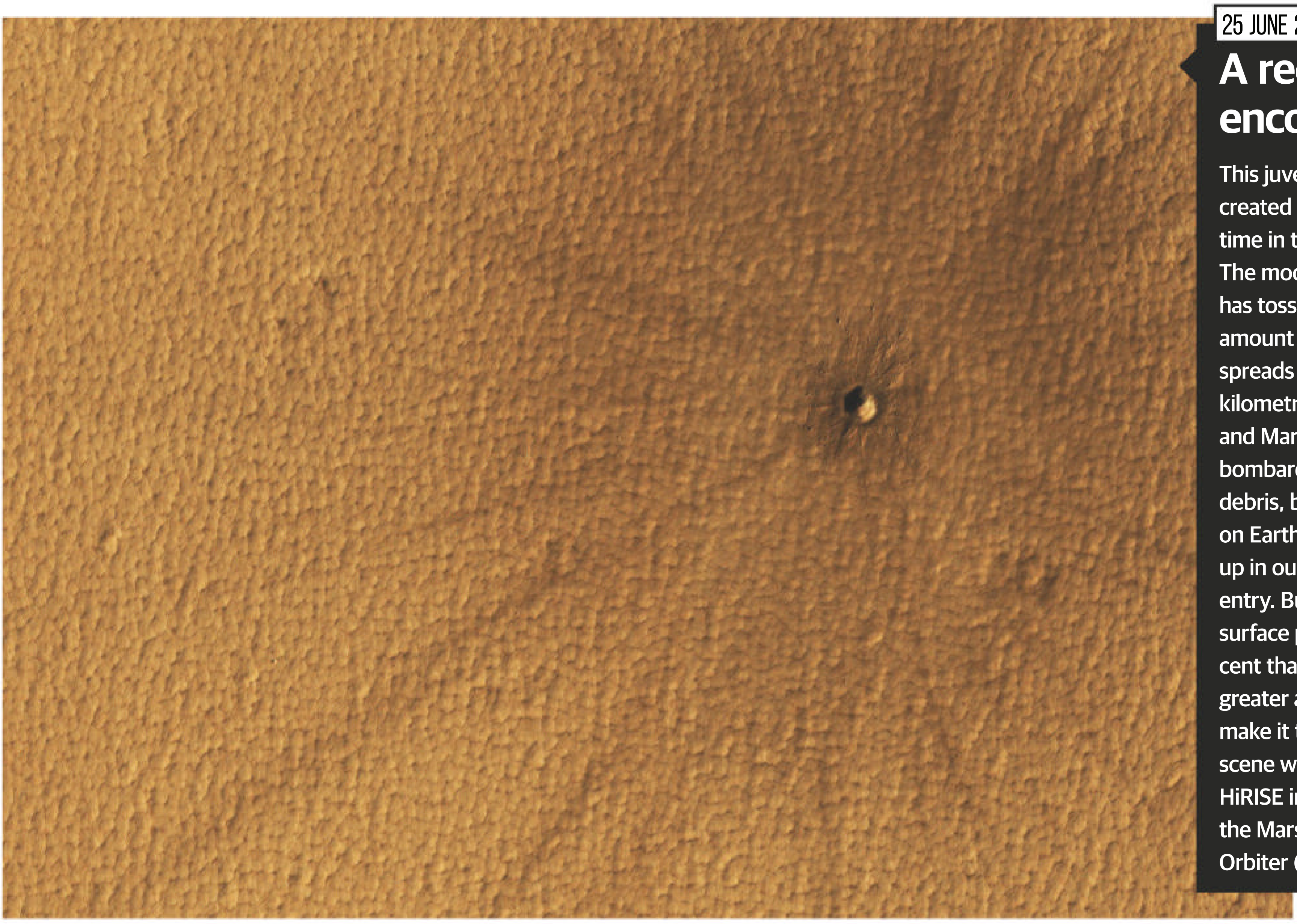
2 JULY 2021

Intergalactic highway

This composite shows a galaxy cluster known as the Northern Clump, around 690 million light years away. Scientists have recently discovered that this cluster is 'hitching a ride' on a colossal strip of hot gas that stretches for at least 50 million light years. The clump is moving towards two other clusters, Abell 3391 and Abell 3395, which are not shown in this image. The filaments of gas between the clusters are acting like intergalactic highways, chauffeuring the clusters through the cosmos before they eventually collide.



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25 JUNE 2021

A recent encounter

This juvenile crater was likely created by an impact some time in the last five years. The modest-looking crater has tossed out an impressive amount of ejecta, which spreads out for almost one kilometre (0.62 miles). Earth and Mars receive regular bombardments from space debris, but we see less of it on Earth as it usually burns up in our atmosphere upon entry. But on Mars the surface pressure is one per cent that of Earth's, so a greater amount of impactors make it to the surface. This scene was captured by the HiRISE instrument on board the Mars Reconnaissance Orbiter (MRO).

ASTRONOMERS SPOT FIRST ACTIVITY ON GIANT MEGA COMET BEYOND SATURN

Words by Elizabeth Howell

Spotting the first signs of activity on a comet of gargantuan size came down to a time-zone advantage. Astronomers in New Zealand were the first to spot a coma spreading around the mega comet C/2014 UN271, also known as Bernardinelli-Bernstein, which may be 1,000 times more massive than a typical comet. It could even be the most massive comet ever found in all of recorded history.

The team that monitors images captured by the Las Cumbres Observatory (LCO) is spread around the world, and images from one of LCO's one-metre telescopes hosted at the South African Astronomical Observatory were available on 23 June at 05:00 BST. That happens to be afternoon in New Zealand. "The other folks were asleep," recalled LCO team member Michele Bannister, of New Zealand's University of Canterbury. At first glance, however, she thought the new imagery was a bust thanks to the ever-present problem of satellites going through the field of view of telescopes. "The first image had the comet obscured by a satellite streak, and my heart sank," she continued. "But then the others were clear enough, and there it was, definitely a beautiful little fuzzy dot, not at all crisp like its neighbouring stars."

What caught Bannister's attention was a foamy coma emerging at an incredible distance from the Sun, as the comet has a lot of mass available to heat up. Bernardinelli-Bernstein's huge core is estimated to be more than 100 kilometres (62 miles) in diameter, three times as large as the next-largest comet nucleus – that of Hale-Bopp, a famous naked-eye comet that passed by Earth in 1998. Unfortunately for eager astronomers, however, Bernardinelli-Bernstein won't get very close to our planet for observations.

Bernardinelli-Bernstein's closest approach to the Sun will still be beyond Saturn in January 2031, but astronomers have a decade to plan for that approach. If history is any guide, telescopes around the world and in space, along with any spacecraft that happen to be nearby, will peer at the comet to learn as much as possible about its composition and history. And the LCO Outbursting Objects Key (LOOK) Project will continue to watch. It's expected to be of help since its network of telescopes allows for a 'rapid response' within 15 minutes whenever any outbursts occur. But LCO won't be the only one.

"There are now a large number of surveys, such as the Zwicky Transient Facility and the upcoming Vera C. Rubin Observatory, that are monitoring parts of the sky every night," said LOOK member Tim Lister, an LCO scientist. "These surveys can provide alerts if one of the comets changes brightness suddenly," he added. "Then we can trigger the robotic telescopes of LCO to get us more detailed data and a longer look at the changing comet while the survey moves on to other areas of the sky."

The comet won't come any closer than Saturn is to the Sun

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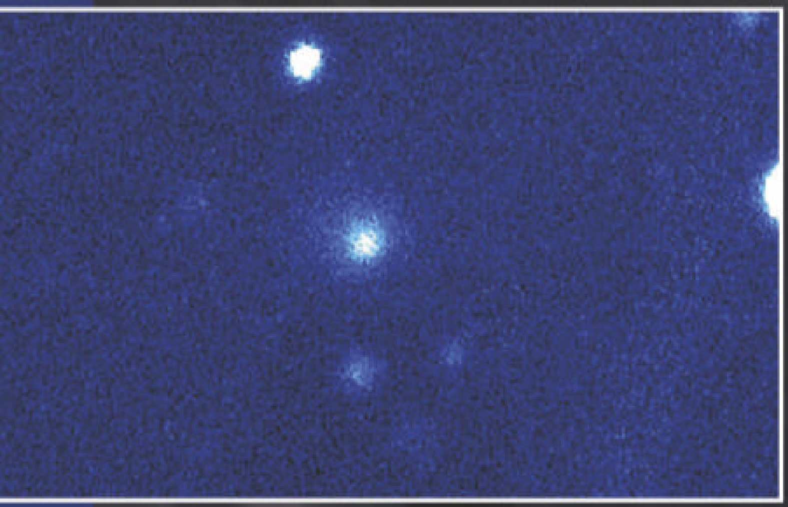

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CURIOSITY ROVER DISCOVERS THAT EVIDENCE OF PAST LIFE ON MARS MAY HAVE BEEN ERASED

Words by Ben Turner

Curiosity made a surprising discovery while investigating clay-rich sedimentary rocks around Gale crater, a former lake that was made when an asteroid struck the Red Planet roughly 3.6 billion years ago. Clay is a good signpost towards evidence of life because it's usually created when rocky minerals weather away and rot after contact with water – a key ingredient for life. It's also an excellent material for storing microbial fossils.

Left: Curiosity landed in Gale crater in 2012

© NASA/JPL

But when Curiosity took two samples of ancient mudstone, a sedimentary rock containing clay, from patches of the dried-out lake bed – dated to 3.5 billion years ago and just 400 metres (1,312 feet) apart – researchers found one patch contained only half the expected amount of clay minerals. Instead that patch held a greater quantity of iron oxides, the compounds that give Mars its rusty hue. The team believes the culprit behind this geological disappearing act is brine: super-salty water that leaked into the mineral-rich clay layers and destabilised them, flushing them away and wiping patches of both the geological and possibly even biological record clean. "We used to think that once these layers of clay minerals formed at the bottom of the lake in Gale crater they stayed that way, preserving the moment in time they formed for billions of years," said Tom Bristow, a researcher at NASA's Ames Research Center. "But later brines broke down these clay minerals in some places – essentially resetting the rock record."

ASTRONOMERS DISCOVER A QUARTET OF TEENAGE ALIEN PLANETS FAR, FAR AWAY

Words by Rahul Rao

Astronomers have discovered a quartet of teenage exoplanets in data from NASA's Transiting Exoplanet Survey Satellite (TESS). The planets in question lie a little over 130 light years away from Earth. They orbit a pair of little orange dwarf stars, each smaller than the Sun, named TOI 2076 and TOI 1808 – TOI is short for TESS Object of Interest. Even though the two stars are not close – they're actually a whole 30 light years apart – they're moving in the same direction, and both stars are around the same age, suggesting that they formed in the same place.

"The planets in both systems are in a transitional – or teenage – phase of their life cycle," said Christina Hedges, an astronomer at the Bay Area Environmental Research Institute and NASA's Ames Research Center in California. "They're not newborns, but they're also not settled down. Learning more about planets in this teen stage will ultimately help us understand older planets in other systems."

Since 2018, TESS has been in Earth orbit, keeping an eye on 75 per cent of the visible sky. It watches for subtle dips in light from stars, which can be telltale signs of planets passing in front of their hosts. TESS finished its initially planned survey in July 2020, but its mission has been extended into at least 2022. Since its launch, the telescope has allowed astronomers to pinpoint more than 2,000 exoplanet candidates.

Below: The planets exist in nearby systems with similar host stars

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RARE 'TEARDROP' STAR AND ITS INVISIBLE PARTNER ARE DOOMED TO EXPLODE IN A MASSIVE SUPERNOVA

Words by Brandon Specktor

Astronomers have discovered a rare, teardrop-shaped star swirling through the cosmos some 1,500 light years from the Sun. Why does the star have this unusual shape? Because it's in a toxic relationship with a partner, which is ripping the life from its body. In stellar relationships like these, there is no amicable uncoupling; the romance only ends when both stars explode in a violent, thermonuclear explosion that's visible across the galaxy. But astronomers are fired up about this twisted stellar relationship. The system, HD265435, is one of only three known binary star systems in the universe - and the closest one to Earth - that is clearly destined to end in a Type Ia supernova.

These types of stellar explosions occur when a white dwarf shares an orbit with a larger, younger star that still has some fuel left to burn. Small but gravitationally massive, the white dwarf gladly gobbles up this fuel, yanking so much matter away from its companion that the younger star begins to change shape from a sphere into an ellipse, or teardrop. The older star grows larger and larger over millions of years, becoming too big for its own good. Nuclear reactions reignite in its core, the dwarf goes boom and both stars become an irradiated smudge of gas and dust in the night sky.

These stars fully orbit each other once every 90 minutes or so, indicating that they are extremely close and will probably merge completely millions of years from now. The pair has the right total mass to suggest that a Type Ia supernova is on the horizon - just another 70 million years or so away.

Above: The star is being warped as a white dwarf companion strips its material

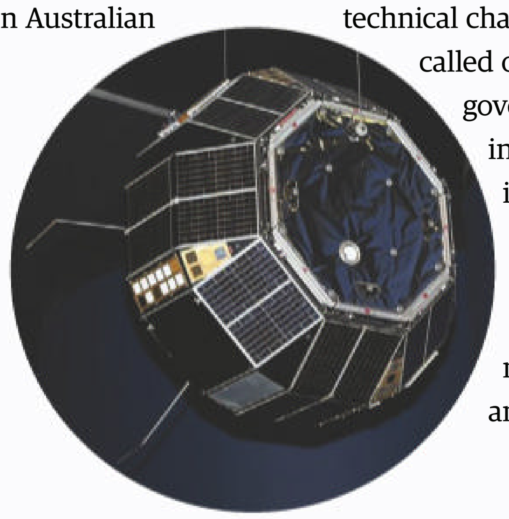
ROCKET START-UP SKYRORA WANTS TO SALVAGE AN ICONIC UK SATELLITE FOR MUSEUM DISPLAY

Words by Tereza Pultarova

Scottish start-up Skyrora wants to retrieve the derelict remains of the iconic satellite Prospero, the only British craft ever launched into space on a domestic rocket, and return it to Earth for a museum display. Based in Edinburgh, Skyrora is currently developing a light kerosene-fuelled rocket capable of launching small satellites to low-Earth orbit. In 2018 the company spearheaded an initiative that retrieved the remnants of the first stage of the British-built Black Arrow rocket, which in 1971 launched Prospero from an Australian desert, and returned it to the UK.

The launch of Prospero has a special - though bittersweet - place in British history. The Black Arrow rocket program, a continuation of the UK's missile defence program, shut down after the successful launch due to cost reasons, leaving Prospero the first - and so far only - British satellite to launch on a British-built rocket. Prospero, which studied the effects of the space environment on telecommunication satellites, sent its last signal to the ground in 2004. Since then its orbit has been slowly decaying as the satellite joins the growing cloud of orbital debris.

Retrieving the 50-year-old Prospero satellite, which still orbits at an altitude of about 1,000 kilometres (600 miles), will present significant technical challenges. Skyrora has therefore called on other UK companies, government agencies and academic institutions to put forward ideas on how to accomplish the task. The UK-based space firm expects to introduce a more detailed plan for the mission by 28 October, the 50th anniversary of Prospero's launch.



Source: Wikimedia Commons © Geni

Left: The company has already retrieved the first stage of the launch vehicle

Right: The team up hopes to make space more accessible

UNISTELLAR TEAMS UP WITH NIKON TO INCREASE ACCESS TO HIGH-TECH SKY-WATCHING

Words by Alexander Cox

Telescope maker Unistellar and camera company Nikon have announced a new partnership to give a wider public of amateur astronomers a chance to use high-end equipment and enjoy the wonders of the night sky just like astronomy professionals.

A lot of the cameras used by astronauts to photograph Earth from above on the International Space Station are made by Nikon, and through the new partnership the optics icon will help Unistellar by sharing its cutting-edge technologies and industrial know-how.

"Like Nikon has done and continues to do in many fields related with optics and imaging, we see Unistellar's products spark joy and excitement on an important and meaningful topic that was previously difficult to grasp for consumers," said Yasuhiro Ohmura, Nikon's senior vice president. "We are also especially sensitive to the unique way Unistellar promotes science and enlightenment at a popular level and are happy to collaborate in widening and furthering this mission."

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WIN

HOMESTAR ORIGINAL PLANETARIUM

Bring the night sky into your home, courtesy of Sega Toys

Enjoy the sight of thousands of twinkling stars from the comfort of your sofa with the Homestar Original from Sega Toys. With its ultra-bright three-watt LED and its rotating movement, this high-definition planetarium projects the Northern Hemisphere's night sky onto your ceiling, enabling you to observe the heavens and map the constellations, even on a cloudy night.

A shooting star function provides a beautifully realistic nighttime experience, while a handy timer lets you fall asleep while gazing at the stars, turning off the planetarium automatically. Complete with an AC adapter, exchangeable projection discs, a manual and astronomical background information, the Homestar Original planetarium from Sega Toys is ideal for the whole family.

To be in with a chance of winning, answer this question:

What is the name of the brightest star in the constellation of Lyra (the Harp)?

A: Spica **B:** Vega **C:** Aldebaran

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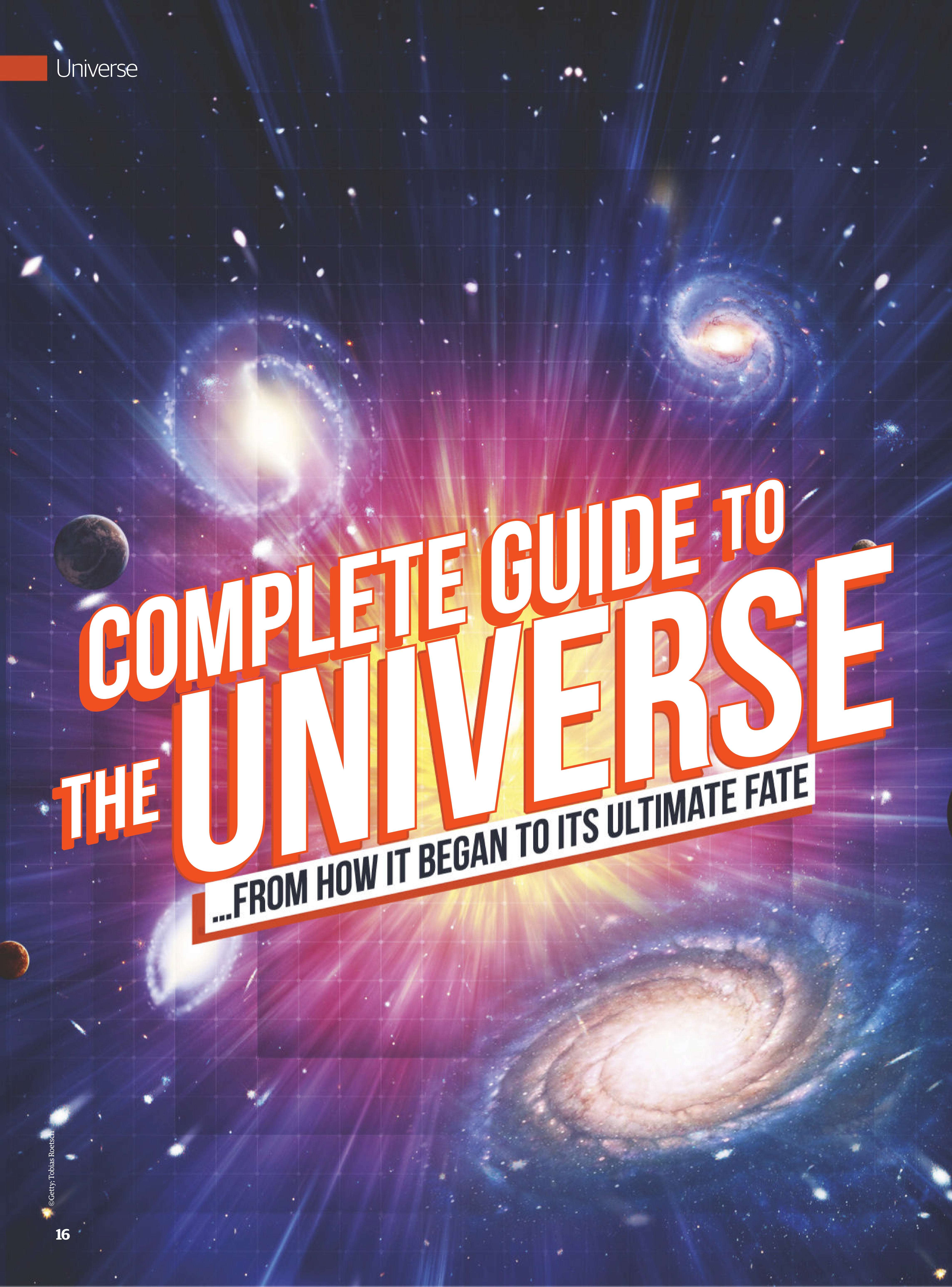


COMPLETE GUIDE TO THE UNIVERSE

…FROM HOW IT BEGAN TO ITS ULTIMATE FATE

©Getty; Tobias Roetsch

Reported by Giles Sparrow

OUR UNIVERSE ENCOMPASSES EVERYTHING AROUND US, COUNTLESS STARS, PLANETS AND GALAXIES STRETCHING AS FAR AS OUR TELESCOPES CAN SEE, WITH VAST EXPANSES BEYOND THEM THAT LIE FOREVER OUT OF SIGHT. IT'S A BIG SUBJECT – THE BIGGEST OF ALL – SO JOIN US AS WE BREAK DOWN THE BASICS

WHAT IS THE UNIVERSE?

The universe is a vast expanse of space and time filled with matter and energy. The word comes from the Latin universus, meaning 'all things', although ours may in fact be just one of many universes in a so-called multiverse. Over the course of billions of years, the simple atoms that formed in the early history of the universe have come together to produce countless galaxies, stars and solar systems like our own, separated by enormous distances. Meanwhile, nuclear processes inside stars, or triggered by their violent deaths, have steadily processed the first simple atoms to enrich later generations of stars, and the space between them, with heavier and more complex elements in an ongoing cosmic recycling scheme.

COSMIC DISTANCES

Astronomers put a scale to the universe by measuring the distance to remote galaxies. The most accurate way of doing this is to look for 'standard candles' - rare objects that are bright enough to see across vast distances and which obey physical rules that reveal their intrinsic luminosity or light output. The most useful standard candles are variable stars called Cepheids, whose pulsation period is linked to their average luminosity. The distance to the host galaxies of these stars can be worked out by comparing their theoretical luminosity to their brightness measured on Earth.

While Cepheids are only detectable in the relatively local universe, the distance measurements they provide are enough to reveal a rule of thumb that can be applied more widely. This rule, known as Hubble's law, links the distance of a remote galaxy to the speed

LIFE IN THE UNIVERSE

One of the most remarkable aspects of the universe is that it's given rise – at least once – to intelligent life. Life of any kind is only possible because of a handful of basic parameters of nature, such as those which control the strength of forces within and between atoms and those that permit the existence of a stable universe at all. The precise values of these parameters allow the creation of stable elements, the existence of habitable planets and the formation of complex molecules.

Instinctively it may feel like this level of 'fine-tuning' is too big a stroke of good fortune to happen by chance, but the so-called anthropic (human-centred) principle points out a possible flaw in this logic: we shouldn't be too surprised that the universe seems fine-tuned for our existence because if its properties were slightly different, we simply wouldn't be around to measure them.

A more immediate question, however, is whether life elsewhere in the cosmos is rare or widespread? Breakthroughs in recent decades, such as the discovery of abundant exoplanets orbiting other stars, have shown that raw materials and suitable habitats for life are certainly widespread, but we still can't be sure that life will always arise wherever conditions are broadly hospitable or whether we're overlooking some vital factor.

EXPLORING THE MULTIVERSE

Many cosmologists believe that our universe is just one within a wider 'multiverse'. Many complex types of multiverse are possible – for instance, a theory called eternal inflation argues that just as our universe arose from one tiny region within the original Big Bang and was then blown up by a sudden event called inflation, the raw material of the Big Bang is still out there, giving rise to new universes with the potential for very different physical parameters to ours.

Another is closer to science fiction's 'parallel' universes, and is rooted in quantum mechanics, the bizarre branch of physics that governs particles on a subatomic scale, within which events always carry a degree of uncertainty. There are many ways of handling this uncertainty, but according to one unusual idea, the 'many-worlds interpretation', every possible outcome of a quantum event occurs, but each one happens in its own distinct universe. In this sense, ours may be just one among a truly infinite number within which things happen to have played out a certain way.

© Adrian Mann

AR SCAN HERE

Above: Voyager 2 is over 17.5 billion kilometres (11 billion miles) from Earth, and will continue its journey out into the universe for years to come

Below: Elusive dark matter can sometimes be mapped due to the effects of its gravity. In this example, dark matter (blue) has separated from hot gas (pink) during the collision between a pair of distant galaxy clusters

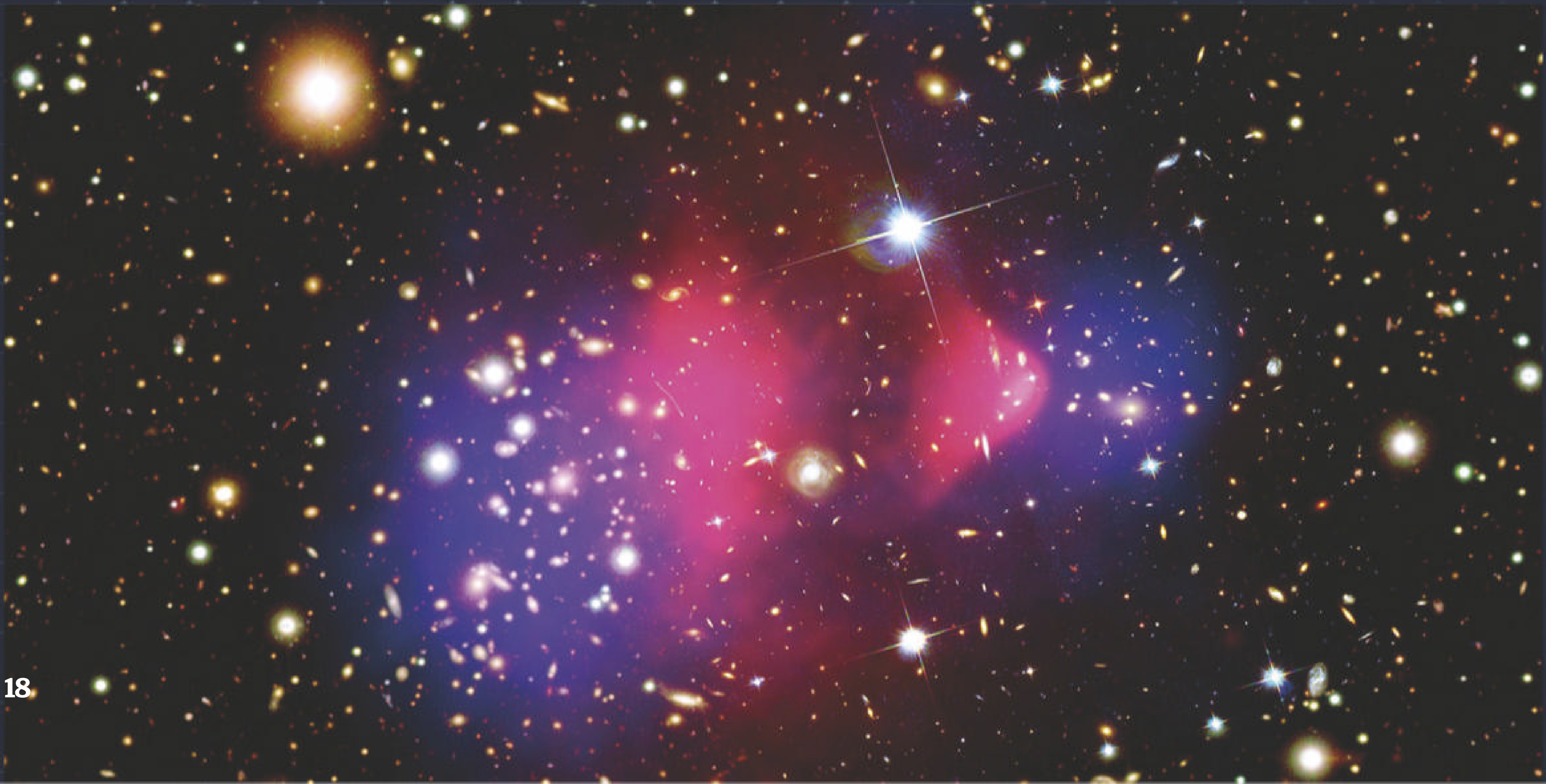
at which it's moving away from us. Hubble's law applies because the universe as a whole is expanding, carrying distant galaxies away from each other like raisins in a rising cake. The wider the separation between galaxies, the faster they move apart, because there is more expanding 'dough' between them. What's more, this expansion stretches light from fast-retreating galaxies into longer and redder wavelengths, creating a 'redshift' that can be measured on Earth and used as a proxy for distance itself. Broadly speaking, the farther away a galaxy lies, the greater the redshift in its light.

EXPANSION AND ORIGINS

Since the universe as a whole is expanding, it must have been much smaller in the past, with matter packed more closely together. Modern measurements of the rate of expansion - known as the Hubble constant - put it at around 21.5 kilometres (13.4 miles) per second per million light years of separation; in other words, on average galaxies 10 million light years apart are receding from each other at around 215 kilometres (134 miles) per second. By winding back the clock of cosmic expansion to zero, we can pin down a time when everything was in the same place: the beginning of the universe, about 13.8 billion years ago. Because matter was packed together more closely in the early universe, it must also have been hotter. In the very earliest times, temperatures were so high that any matter that formed would have fallen apart - in effect, matter and energy were interchangeable in line with Einstein's famous equation $E=mc^2$. However, as temperatures cooled, more complex forms of matter were able to persist for longer, eventually forming stable atoms of simple elements such as hydrogen and helium. This is the origin of the Big Bang theory - our best explanation for how the universe began.

COSMIC TIME MACHINE

An intrinsic property of the universe is that the speed of light in a vacuum is constant. Light moves at 299,792 kilometres (186,282 miles) per second - a speed that seems instantaneous in everyday life, but which is nevertheless finite - and this has important consequences for how we view distant space. In essence, the further away we look in space, the further we are looking back in time, since light must have left objects long ago to reach our telescopes now. The evolution of stars and galaxies is so slow that the millions of years taken by light from nearby galaxies makes little difference, but as telescopes and detectors have improved, it's become possible to see objects that are many billions of light years away - so distant that we are looking back to a much earlier phase of cosmic history, when they were just beginning to form.



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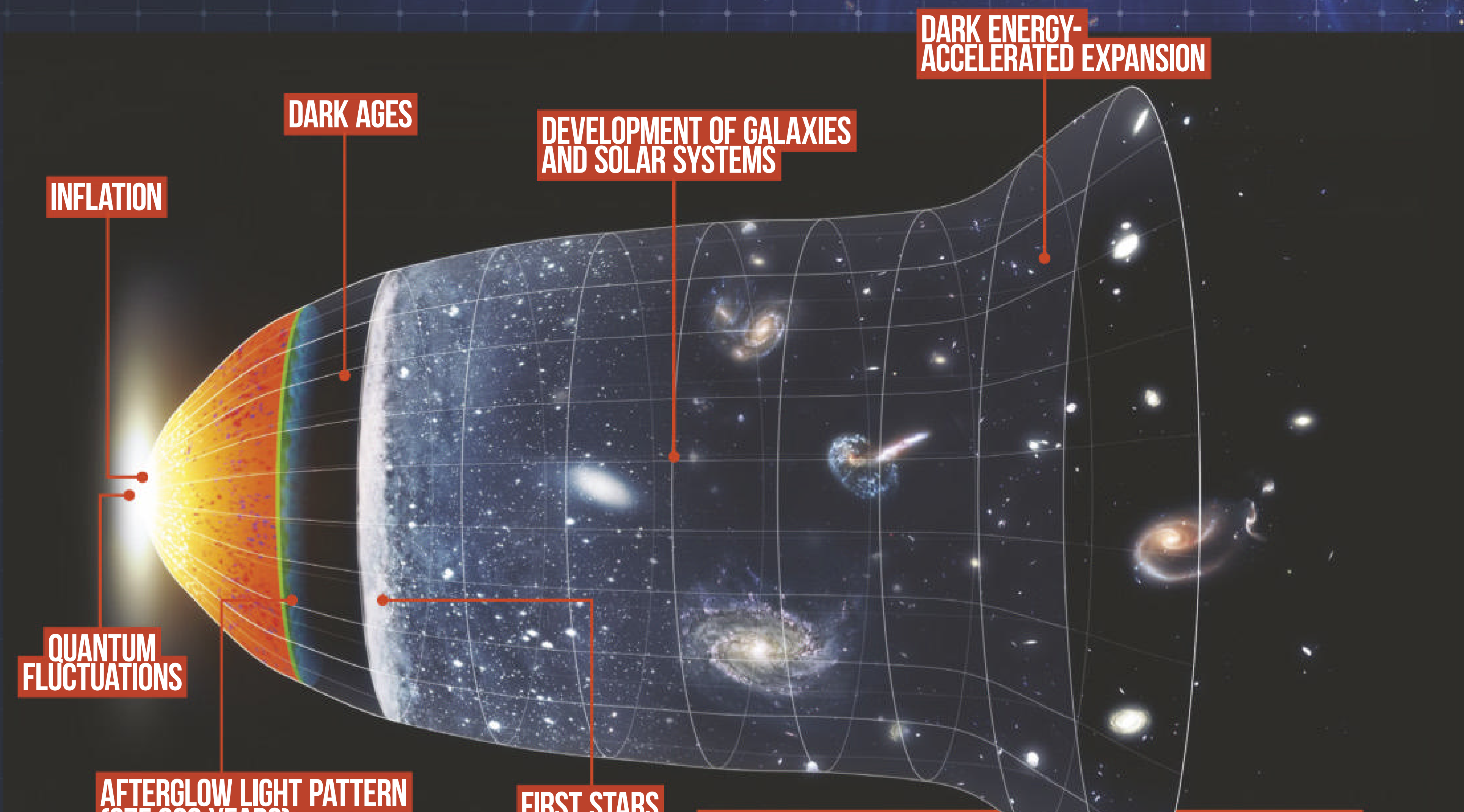
Right: The Big Bang created the space, time and energy that makes up our universe some 13.8 billion years ago. After an initial dramatic event called inflation, all matter was formed in minutes, with the first atoms coming together 380,000 years ago, at which point the universe became transparent

Bottom right: The most distant galaxy so far detected, known as GN-z11, exists about 400 million years after the Big Bang itself


DARK ENERGY-ACCELERATED EXPANSION
DARK AGES
DEVELOPMENT OF GALAXIES AND SOLAR SYSTEMS
INFLATION
QUANTUM FLUCTUATIONS
AFTERGLOW LIGHT PATTERN (375,000 YEARS)
FIRST STARS

© Tobias Roetsch

TAP HERE TO PLAY

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The first objects to be spotted at these immense distances were quasars – galaxies with monster black holes at their centres that have not yet settled down into a quiet slumber, still actively feeding on gas and dust from their surroundings. Intense light and other radiation from their central regions gives them a star-like appearance, and the surrounding galaxies only became visible as images improved. Telescopes such as the Hubble Space Telescope, meanwhile, have allowed astronomers to detect the light from fainter galaxies even closer to the Big Bang, revealing an era of chaotic mergers as small galaxies grew into larger ones such as today's spiral and elliptical systems.

THE EDGE OF THE UNIVERSE

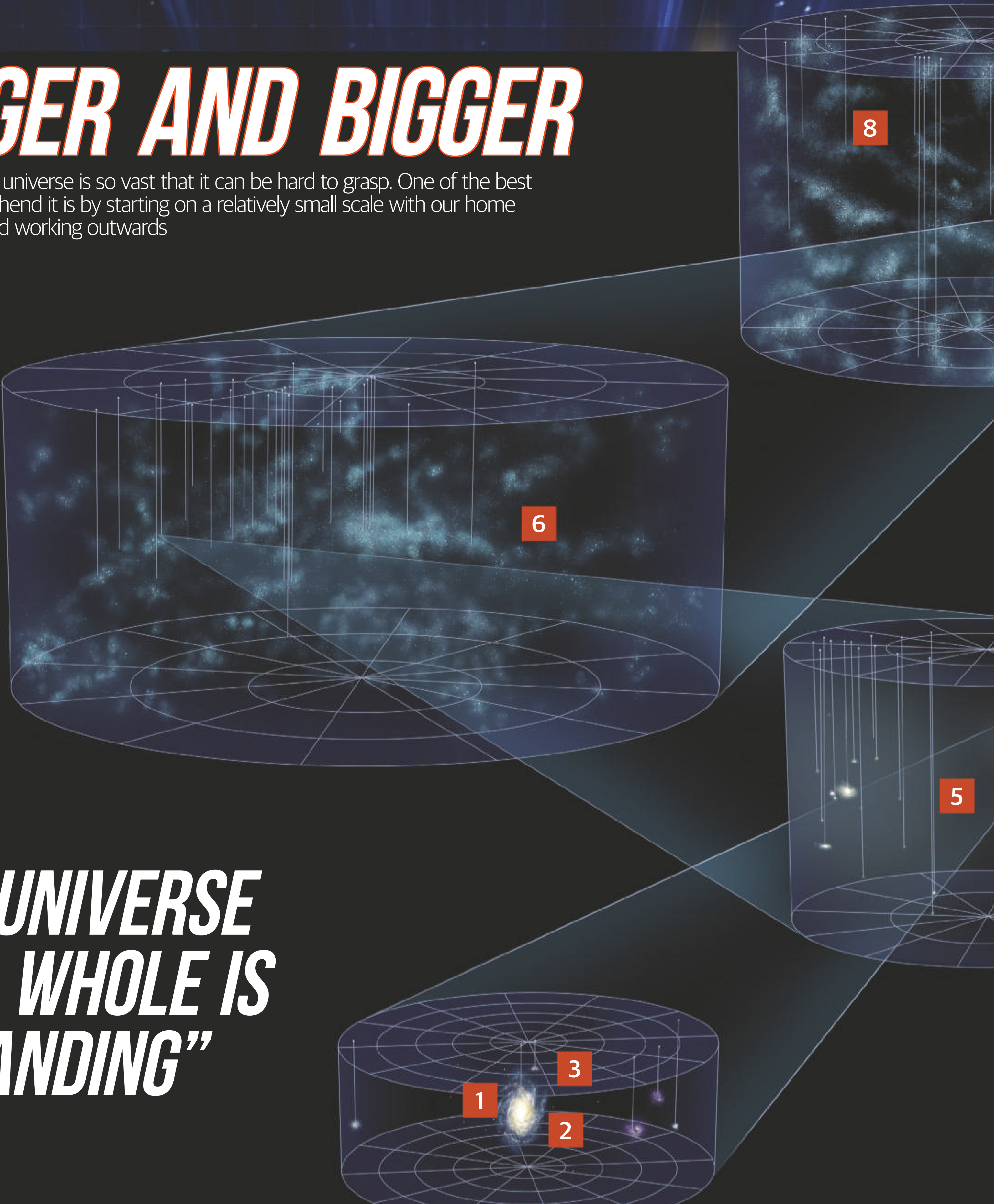
The finite speed of light puts a barrier around 'our' universe that we cannot penetrate. Since radiation has only had 13.8 billion years to reach Earth, it's impossible for any information to reach us from remote parts of the universe beyond 13.8 billion light years. This defines our 'observable universe', a vast bubble of space centred on Earth. Objects at the very edge of this bubble are still too faint and distant for our telescopes to capture. Before the first galaxies, an early generation of truly monstrous stars were the first luminous objects to light up the young universe, and it's hoped that some of these may finally come into view with the launch of the giant James Webb Space Telescope later this year. Beyond these lies the 'cosmic dark age', a period of around 400 million years after the incandescent Big Bang had cooled into invisibility, during which matter coalesced in darkness.

There's another reason for the darkness at the very edge of our observable universe. As the speed at which distant regions and objects are retreating from us gets ever more extreme in all directions, light is stretched and redshifted beyond the limits of visibility – first into the invisible infrared part of the spectrum, and then into microwaves, which are short-wavelength radio waves. The most distant radiation of all comes from the cosmic microwave background (CMB) – a faint signal that comes from all over the sky. It's the afterglow of radiation that escaped from the incandescent fog of matter and trapped light when the universe finally cooled enough to become transparent, about 380,000 years after the Big Bang itself.

> "MORE COMPLEX FORMS OF MATTER WERE ABLE TO PERSIST"

BIGGER AND BIGGER

The scale of the universe is so vast that it can be hard to grasp. One of the best ways to comprehend it is by starting on a relatively small scale with our home planet, Earth, and working outwards



> “THE UNIVERSE AS A WHOLE IS EXPANDING”

1 EARTH

Earth's diameter is 12,756 kilometres (7,926 miles). The Moon orbits Earth at an average of 384,400 kilometres (238,855 miles).

2 SOLAR SYSTEM

The outermost planet in the Solar System, Neptune, orbits the Sun at a distance of 4.5 billion kilometres (2.8 billion miles).

3 LIVING LOCAL

Stars in our local region of space are separated by light years – tens of trillions of kilometres. The brightest star in the sky, Sirius, is 8.6 light years away.

4 HOME GALAXY

Our Sun and Solar System, and all the stars in our sky, are members of the Milky Way – a vast spiral of stars that's roughly 120,000 light years across.

5 GROUPING UP

The Milky Way is a major member of a small galaxy cluster called the Local Group, occupying a volume of space about 10 million light years across.

6 BIG CLUSTER

The Local Group is an outlying region of our local galaxy supercluster, sometimes called the Virgo or Laniakea Supercluster. It is over 100 million light years long.

7 EMPTY SPACE

The Virgo Supercluster is part of a local supercluster complex a billion light years across. At this level, the large-scale structure of filaments and empty voids begins to emerge.

© Nicholas Forder

8 **FAR-REACHING** The observable universe has a diameter of about 93 billion light years based on the current locations of regions that we can see.

UNIVERSE BY NUMBERS

200 BILLION

Estimated number of galaxies in the observable universe

9.46 TRILLION KILOMETRES

A light year, the distance light travels in one Earth year

46.5 BILLION LIGHT YEARS

The distance of an object at the limit of our observable universe

2.726K

The measured temperature of CMB radiation in Kelvin

21.5KM/S PER MILLION LIGHT YEARS

The average rate at which objects move away from each other in the universe due to the expansion of space

MATTER AND FORCES

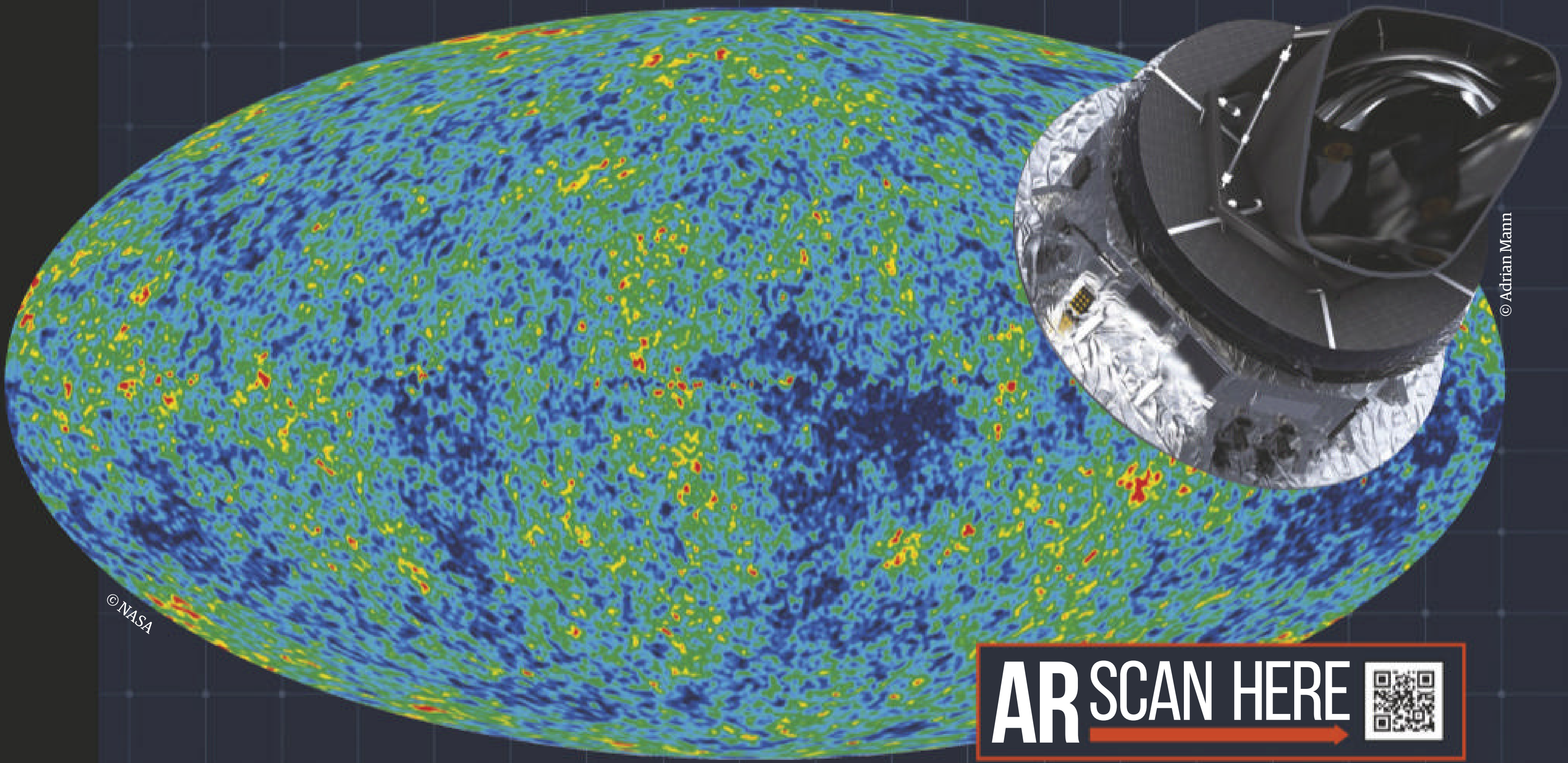
The way that matter is spread across the universe is controlled by four fundamental forces, which influence different types of matter in different ways. Visible matter is composed of tiny atoms that are bound to each other by the electromagnetic force. These are built from even smaller elementary particles held together by both electromagnetism and two 'nuclear forces' that are much more powerful but only operate across tiny distances.

When matter accumulates in large quantities, another force, gravitation, or gravity, comes into play. Gravitation attracts objects with mass. It's extremely weak between individual atoms, but grows stronger as they accumulate in bulk, and has an effectively limitless range. By drawing material together on a variety of scales, gravity is responsible for the formation of stars, galaxies and even galaxy clusters. However, there has not been enough time since the universe was born for it to have shaped the very largest structures in the universe: billion-light-year chains or filaments of galaxy clusters and superclusters that surround apparently empty voids. This large-scale distribution of matter originates instead from density variations that have been with the universe since birth. Such 'ripples' can be seen as tiny differences in the wavelengths of the CMB radiation released as the universe became transparent.

DARK MATTER AND DARK ENERGY

The visible matter that produces and interacts with light and other forms of radiation amounts to just five per cent of all the matter in the

Below: The cosmic microwave background marks the edge of our observable universe - a wall of light red-shifted into microwaves from the moment that the universe first became transparent, about 380,000 years after the Big Bang



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universe. The remainder, 'dark matter', is not only dark, but also transparent and completely unaffected by radiation. It gives itself away only through its gravitational influence, altering the rate at which galaxies rotate and affecting the movement of galaxies within clusters. The nature of dark matter is a mystery, but astronomers have ruled out some possibilities.

We can be pretty sure that it's not just made up of small, dark objects that are undetectable through current instruments - for example stray planets, failed stars or black holes. Studies show that there simply aren't enough of these to make much difference. Meanwhile, models of the matter's distribution based on its gravitational effects show that it clumps loosely around visible objects. It's not spread uniformly across the universe and it's not an explanation for the relatively empty voids of space in the large-scale cosmos. The current best guess is that dark matter is predominantly made from one or more unknown types of elementary particles, known as weakly interacting massive particles (WIMPs). This name says very little about what the particles actually are, and standard models of particle physics do little to address the question, but it seems that answers are most likely to emerge from 'new physics' discovered in experiments such as the Large Hadron Collider than through direct astronomical observations.

Meanwhile, there's another even more elusive and troubling 'substance' in the universe. The presence of so-called 'dark energy' was discovered in the late 1990s when astronomers found evidence that cosmic expansion is currently accelerating, rather than slowing down as we might expect due to the gravity of all the matter in the universe. Calculations show that it must account for around 71 per cent of all the energy in the universe. The nature of dark energy remains puzzling, and some still say the evidence for it is inconclusive. Among those who support the theory there are two popular explanations: it may be either an intrinsic property of space itself, or a 'fifth force' that acts like a form of antigravity on very large scales.

Above: Cepheid variables are ideal for measuring the distance of relatively nearby galaxies

Right: Large clusters like Abell 2744 are the biggest objects governed entirely by gravity

TAP HERE TO PLAY

FATE OF THE UNIVERSE

While 13.8 billion years is a long time, the universe is still young in some respects - some stars shining today formed alongside the first galaxies, and even our Sun is more than one-third the age of the universe. So what will happen to it in the future? On the largest scales, the fate of the cosmos is determined by the balance between its tendency to expand and the inward pull of gravity from all the matter it contains. Astronomers used to assume cosmic expansion would naturally slow down over time. This could lead to a universe that grew ever more slowly, with an effectively infinite life span during which stars would gradually process all of their available materials until they no longer had fuel to shine, and even matter itself might eventually disintegrate. In contrast to this 'Big Chill' scenario, gravity might win out and reverse the expansion of space, drawing everything back into a hot, dense 'Big Crunch'. For a long time, estimates of the density of matter in the universe placed it on the fence between these two possible fates.

But the discovery of dark energy changes the game. Since it appears to accelerate expansion, it seems a 'Big Chill' is almost guaranteed. However, there is also evidence that dark energy has grown more powerful over time. If this is indeed the case, then expansion might continue to accelerate, overwhelming gravitation on ever smaller scales. This could lead to a 'Big Rip' in which galaxies, solar systems and eventually individual atoms are torn apart by the expansion of the space in which they exist. Fortunately, most measurements think such events are a long way off. Our universe, with all its wonders, will be around for a long time yet.

Giles Sparrow
Space science writer
Giles has degrees in astronomy and science communication and has written many books and articles on all aspects of the universe.

SATURN
80 MINUTES

JUPITER

MARS
12.6 MINUTES

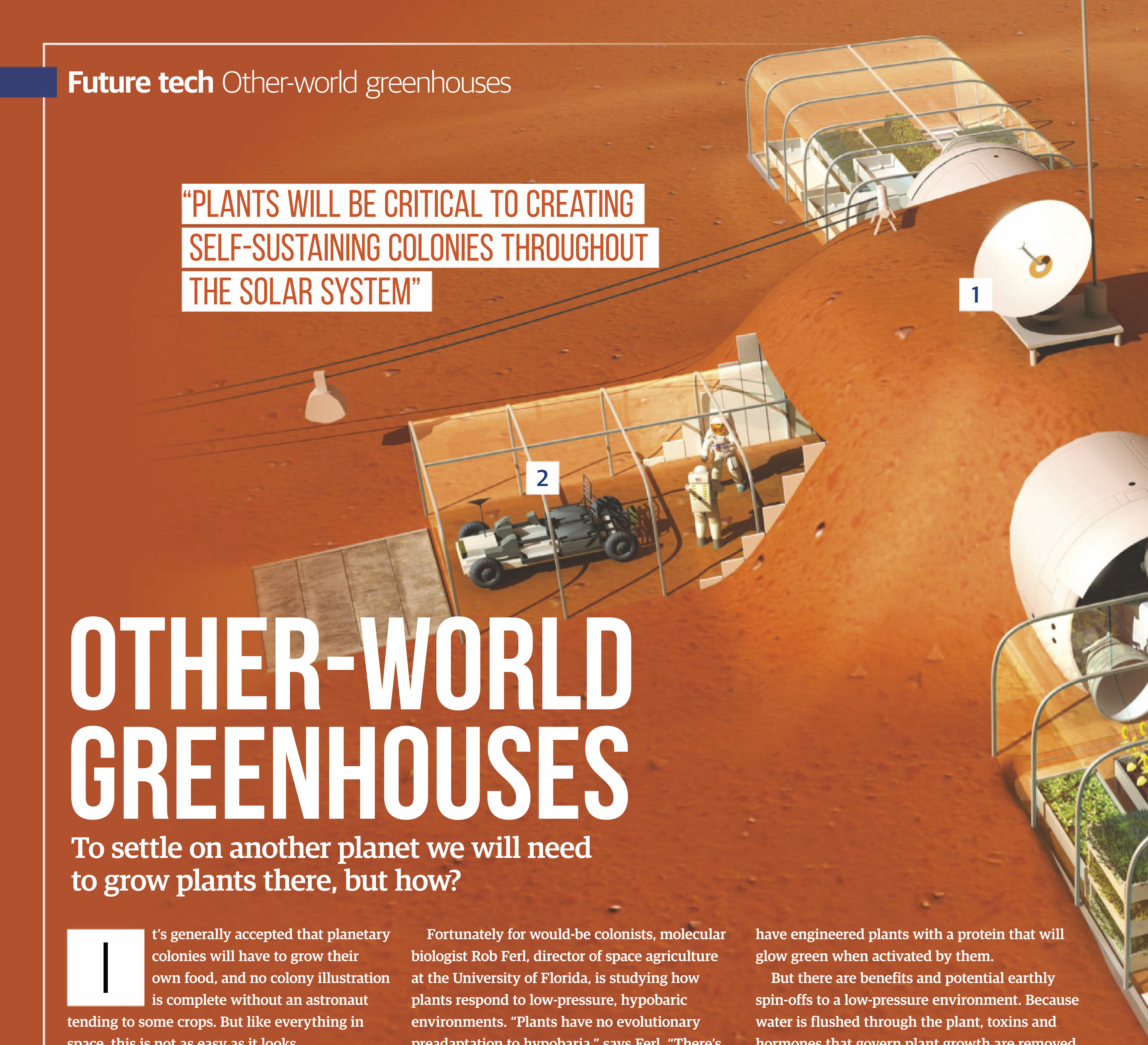
MOON

NEPTUNE
30 MINUTES

VENUS
60 MINUTES

SVD

FUTURE OF SPACE VEHICLE DEPOLOYMENT



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> "PLANTS WILL BE CRITICAL TO CREATING SELF-SUSTAINING COLONIES THROUGHOUT THE SOLAR SYSTEM"

OTHER-WORLD GREENHOUSES

To settle on another planet we will need to grow plants there, but how?

It's generally accepted that planetary colonies will have to grow their own food, and no colony illustration is complete without an astronaut tending to some crops. But like everything in space, this is not as easy as it looks.

Various plants have been grown on the International Space Station, but the problem for planetary greenhouses is not the lack of gravity, but the lack of pressure. In the initial stages of colonisation, most materials and equipment will have to be brought from Earth, and if you can grow plants at a lower atmospheric pressure, it will save a lot of mass.

Air may need to be transported from Earth, and even if there are convenient deposits of ice to split oxygen from, you still need nitrogen and carbon dioxide to make plant-friendly air, which add mass. Greenhouses on the Moon and Mars would need to operate under little or no atmospheric pressure. Until colonies can make engineering materials, the structure will need to be transported. If the pressure inside can be minimised, it will make it much lighter.

Fortunately for would-be colonists, molecular biologist Rob Ferl, director of space agriculture at the University of Florida, is studying how plants respond to low-pressure, hypobaric environments. "Plants have no evolutionary preadaptation to hypobaria," says Ferl. "There's no reason for them to have learned to interpret the biochemical signals induced by low pressures. They don't. They misinterpret them."

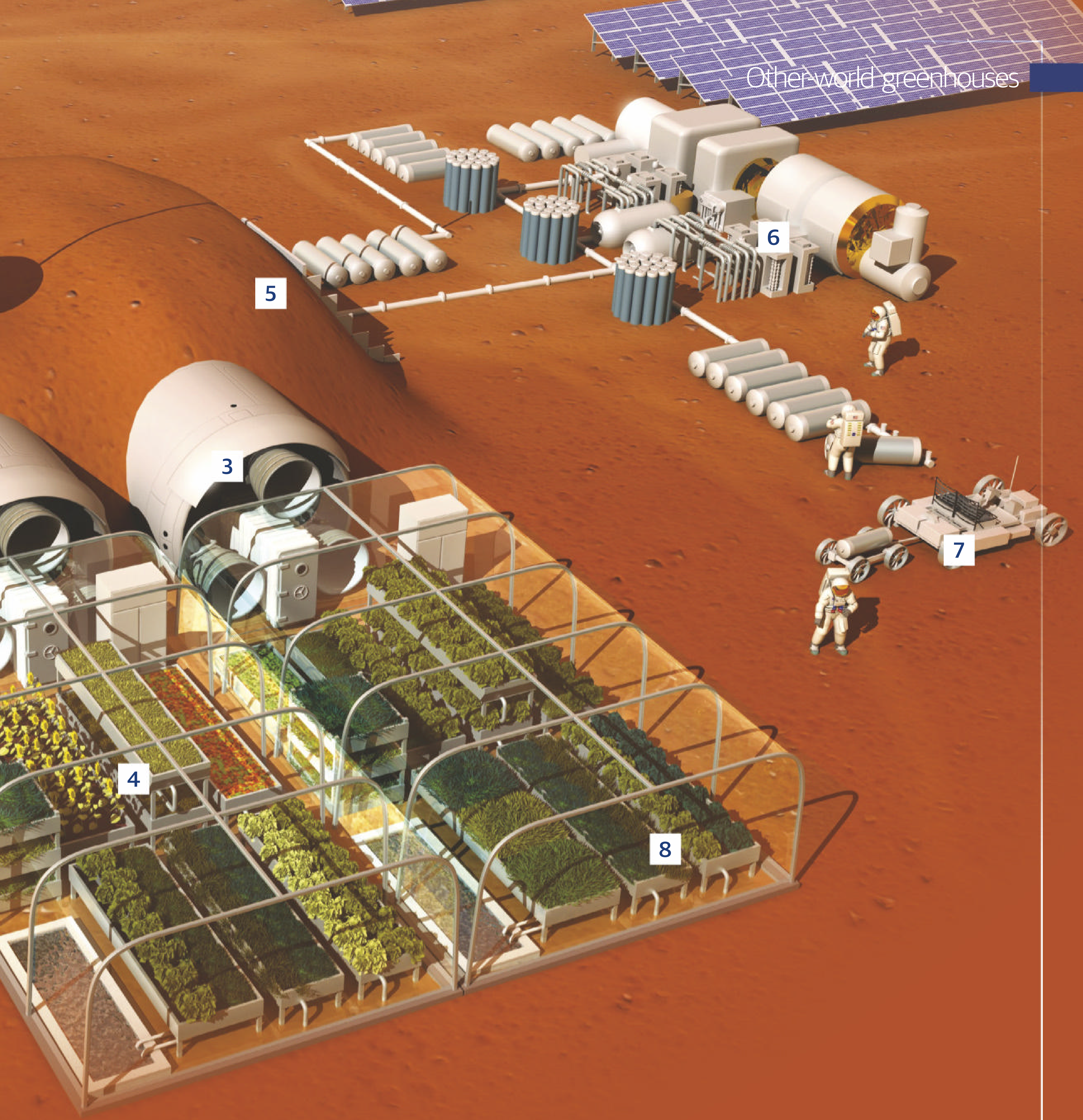
Ferl has found that low pressures - a tenth of normal atmospheric pressure - make plants react as if there is a drought, even when they are provided with ample water and the air is kept humid. Water is drawn out of the leaves much quicker than normal, and this stimulates the plants' genetic response to drought.

The problem is that this will put stress on plants and make growing them more difficult. They may close the tiny pores in their leaves to conserve water or allow their leaves to shrivel up and die. Ferl is studying these responses and testing biochemical alterations to change how plants react to this effect. To track how different genes respond to these conditions, Ferl's team have engineered plants with a protein that will glow green when activated by them.

But there are benefits and potential earthly spin-offs to a low-pressure environment. Because water is flushed through the plant, toxins and hormones that govern plant growth are removed quicker too. This might keep plants healthy for longer, and on Earth it may be possible to make use of this: fruit stored at a low pressure can be kept longer because it removes the chemicals that control ripening.

Ferl now hopes to test plants for longer periods of time over a wider range of pressures, since plants will be critical to creating self-sustaining colonies throughout the Solar System: "The exciting part of this is that we're beginning to understand what it will take to really use plants in our life-support systems."

Attempts to live in space are often plagued by unexpected complications when living systems are removed from the conditions they evolved in, but thanks to Ferl's work we should have one less problem to deal with when it comes to growing our own food on Mars.



1 COMMUNICATIONS It doesn't take much power to communicate with Mars, but it takes between 3 and 22 minutes for signals to travel each way, making normal conversations impossible.

2 ROVER GARAGE Rovers and other equipment may be stored in low-pressure enclosures. The slight pressurisation would make it easy to build and help keep dust out.

3 REPURPOSED SPACECRAFT Everything taken to Mars will need to have as many uses as possible; in this illustration, the cargo landers have been converted into crew quarters.

4 FIVE A DAY Colonists will need to grow a wide range of crops to create a balanced diet, and many varieties will need to be acclimatised to low pressure.

5 SOIL SHIELDING Mars' thin atmosphere and minimal magnetic field provide little shielding from solar radiation and cosmic rays: soil piled over the base will provide effective local protection.

6 ATMOSPHERIC CONVERTER Many Mars mission concepts include plans to extract oxygen and carbon monoxide from the atmosphere. This carbon monoxide can actually be used as a rocket fuel.

7 BATTERIES NOT INCLUDED Robert Zubrin's Mars Direct mission plan intends to use locally captured fuel and oxygen to power ground vehicles so they wouldn't have to bring batteries from Earth.

8 LOW PRESSURE Because of the low internal pressure, the greenhouses could be lightly constructed, looking more like Earth greenhouses than round, pressurised spacecraft. This saves launch mass.

INTERVIEW

BIO

Steven Freeland

Freeland is emeritus professor at Western Sydney University. He is a member of the Australian Space Agency Advisory Board. He has represented the Australian Government at United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) meetings, and in June 2021 was appointed by COPUOS as vice-chair of a five-year working group addressing issues related to the exploration, exploitation and utilisation of space resources.

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STEVEN FREELAND

"WE ARE AT A CROSSROADS WHEN IT COMES TO SPACE"

Steven Freeland speaks to **All About Space** about the importance of space law, the future of space travel and who is liable when something goes wrong

Interviewed by Daisy Dobrijevic

What is space law?

Space is incredibly important for us. We use it many times a day without even thinking. It's not just your phone, it's so many things, as diverse as financial transactions to aircraft navigation to agriculture to disaster management. There's also a highly commercial, global $400 billion [£290 billion] space industry that is growing exponentially. Space is also a critical part of infrastructure for national security and military purposes and, of course, is about science, culture, religion and many aspects of civil society.

Space is ubiquitous, but also incredibly multifaceted, highly strategic and highly (geo)political. It's crucial, therefore, that we have developed a fundamental body of international law to regulate and compel responsible behaviour in outer space, which unlike airspace is an area beyond national jurisdiction.

The legal characterisation of airspace was already categorised by the 1919 Paris Convention as the exclusive jurisdiction of the underlying country. Thus, UK law applies to UK airspace. In general terms, I cannot enter another airspace without permission.

By contrast, when in 1957 Sputnik 1 was launched into Earth orbit and began 'overflying' many countries, nobody asserted that somehow the USSR should have obtained prior permission from any of those countries. It was therefore assumed - and this is reflected in the formal rules that have followed - that there were fundamental differences between how law regards airspace (national jurisdiction) and outer space (beyond national jurisdiction). UK law does not apply to outer space 'above' its territory - rather this is governed by international (space) law.

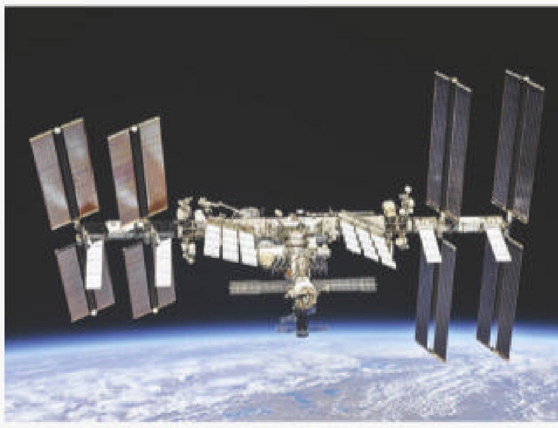
Where does airspace 'end' and space 'begin'?

There's no agreement as to where any boundary might exist, or whether we need one at all. Each year at COPUOS meetings the issue of the definition and delimitation of outer space is discussed. Many of the almost 100 member states will make statements calling for a boundary to be agreed so as to clearly designate the upper limits of a country's sovereignty. Other space-faring nations assert there's no need for such a boundary. This debate has been going on for over six decades with no end in sight, essentially due to politics.

Can law keep up with current developments in space technology?

One of the criticisms you might hear about international space law is that the treaties are all decades old, and as technology has developed, they're no longer relevant. I completely disagree. The space law treaties provide foundational principles that have served us well and will continue to serve us well in the future. They have, in essence, allowed for space to 'work' thus far - notwithstanding the undoubted challenges - and have meant that space has not become an area of conflict. It's no doubt competitive, and that is to be expected, particularly given the strategic and commercial nature of space. But our exploration and use of space has provided such incredible benefits to the whole of humanity and is inextricably tied up with the future of humanity.

That said, of course we will need to augment and supplement the 'rules of the road' regarding space with additional agreed norms and principles to more specifically cover new space activities



Right: Different laws apply to different areas of the ISS

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Above: On 12 May 2021, robotic operators noticed a hole in the ISS' Canadarm2, made by a piece of space debris

Left: Future exploitation and exploration of celestial objects will need governance

made possible by rapid technological advancement. The importance of the existing principles remains clear even in this changing environment, just as the fundamental principles of, for example, the 1949 Geneva Conventions remain crucial to the conduct of armed conflicts, notwithstanding the rapid technological changes to warfare over the past 70 years. Law will never fully keep up in areas where technology races ahead – yet it still provides the fundamental basis within which those new technologies must operate.

Who has jurisdiction on and over a spacecraft?
International space law establishes a registration system, which has effects somewhat like the registration system for ships. Each party to the relevant space treaty is required to maintain a national register, in which it would enter details of those space objects that have been launched into Earth orbit or beyond, and over which it retains jurisdiction and control, both in relation to the object itself and any personnel on board. As a state of registry, therefore, that county's jurisdiction would apply to that satellite and its crew and any spaceflight participants.

What about the International Space Station?
The International Space Station (ISS) is probably the most complex cooperative infrastructure project we have ever seen, with the US, Russia, Japan, Canada and 11 European countries as participants. From a registration perspective, however, the ISS is regarded as a series of separate modules. Each participant has registered specific modules of the ISS in its own national register, meaning that, in effect, different national laws apply in different parts of the ISS.

For example, US law applies to the areas of the ISS that the US has registered, Russian law applies to its modules and so on. This was an agreed ad hoc solution because the participants didn't wish to relinquish their jurisdiction over the parts that they had contributed to the overall structure.

This even extends to situations where a crime might be committed on board. We quite recently saw an example where an American astronaut had allegedly unlawfully hacked into her ex-partner's bank account while in the American part of the ISS. In that case, it was pretty straightforward – American criminal law would apply – but it could become more complicated depending on the circumstances.

As we move towards possible future permanent human settlements in space or on celestial bodies like the Moon, we will need to work out an appropriate model to determine what laws and jurisdiction will apply, as well as the content of those laws themselves, given the unique environment in which they will be living. These are difficult and complex questions to resolve.

Who is liable for collisions and falling debris?
If an orbiting or falling satellite collides with another satellite, damage will almost certainly result. International space law establishes a liability regime to deal with such collisions, as well as where space debris falls to Earth, causing damage. The regime establishes that the 'launching state(s)' will bear such potential liability, either on a fault basis [for collisions between space objects] or an absolute/strict basis where the damage is on Earth or to an aircraft in flight.

Unusually, this liability falls on the relevant countries, even where the space object that causes the damage is owned and/or operated by a private entity. If a satellite owned by a UK company was launched from French Guiana, both France and the UK are regarded as launching states. If parts of this satellite were to fall on a house in Melbourne, Australia could potentially, under international space law, seek compensation for the damage from the UK, France or both. If this UK satellite were to collide with another satellite in space, liability would be determined on the basis of fault. Again, the countries themselves – as launching states – would be liable. Thus there will always remain a risk to a country when a private entity within its jurisdiction conducts a space activity. The risks are relatively small, but increasing over time.

As part of the national licencing system, therefore, the relevant government authority might require some form of financial indemnity, protection or insurance from the applicant as a condition of granting the licence.

In the past, private space companies have typically been large organisations that could meet such conditions relatively easily. With reduced barriers to space due to 'miniaturisation' technology, many smaller and start-up companies are now seeking to access space. For them, existing financial imposts and conditions may make the planned mission unfeasible. Governments will have to rethink how much of a risk they are willing to bear in order to encourage industry, innovation and entrepreneurship while recognising that, if something goes 'wrong', it may itself be on the hook. It's a balancing act which every government must consider as it drafts new national space legislation or reforms its existing laws.

What law applies to the Moon and Mars?

International space law also applies to celestial bodies within our Solar System, like the Moon and Mars, despite what some corporations might assert. There are important principles that apply to activities on celestial bodies, but we clearly will need to think carefully about augmenting these to provide clarity for future activities. There is now great excitement about the possible exploitation of space resources on celestial bodies. This is a 'big' issue that will define our future relationship with space. There are many conversations on this issue taking place at all levels, and COPUOS has been actively engaged and has recently established a working group on the issue.

What principles are important going forward?

For me there are three overarching principles as we continue to meet the challenges and opportunities arising from rapid development of space technology. We are now doing things that were beyond the comprehension of people even 10 to 15 years ago, let alone when the foundational treaties were agreed. We really don't know what might be possible in even five years from now. We need to adhere to the fundamental principles of space law, but we need more guidance.

Notwithstanding the 'terrestrial' geopolitical tensions, all countries - and particularly the major space-faring nations - have much more in common in space than they have differences. Their utilisation of space has allowed them to do incredible things, to grow and develop and maintain competitive advantages over other countries. They have significant space assets as part of the critical infrastructure on which they rely, and are therefore highly dependent on space and most vulnerable if certain lines are crossed. It's clearly in all of their interests that the use of space is not compromised by irresponsible behaviour.

The second overarching principle is humanity. The future of humanity is linked to space. It's a crucial part of everything we do on Earth now, and impacts on everyone's lives, livelihoods and human rights. We must stay loyal to notions of humanity as we move forward.

My third overarching principle arises from our stewardship relationship, not just with Earth, but also with space. We are custodians of the planet - though we're not doing a great job at that - but also of space, for current and future generations. There's so much to enjoy and wonder about space, and we must ensure that those elements remain. We can't afford to repeat the same mistakes.

Overall, we are at a crossroads at this moment when it comes to space. If we stray down the wrong path, there may be a point where the damage becomes irreversible. In my opinion, everything we do in the governance of space should be directed towards responsible behaviour, avoiding conflict and maintaining the stability, safety and sustainability of space.

> “OUR EXPLORATION AND USE OF SPACE HAS PROVIDED SUCH INCREDIBLE BENEFITS TO THE WHOLE OF HUMANITY”

Below: Possible future human settlements on Mars will need appropriate laws and jurisdiction

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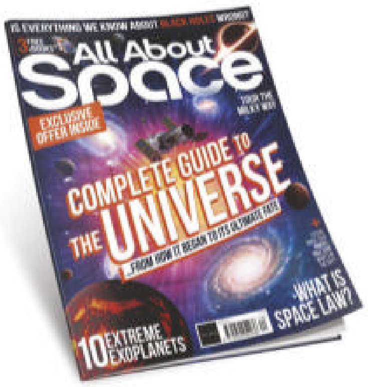

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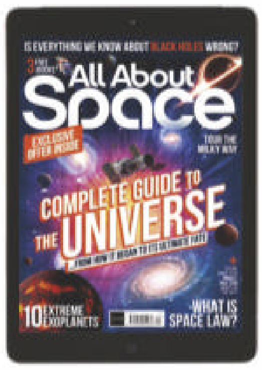

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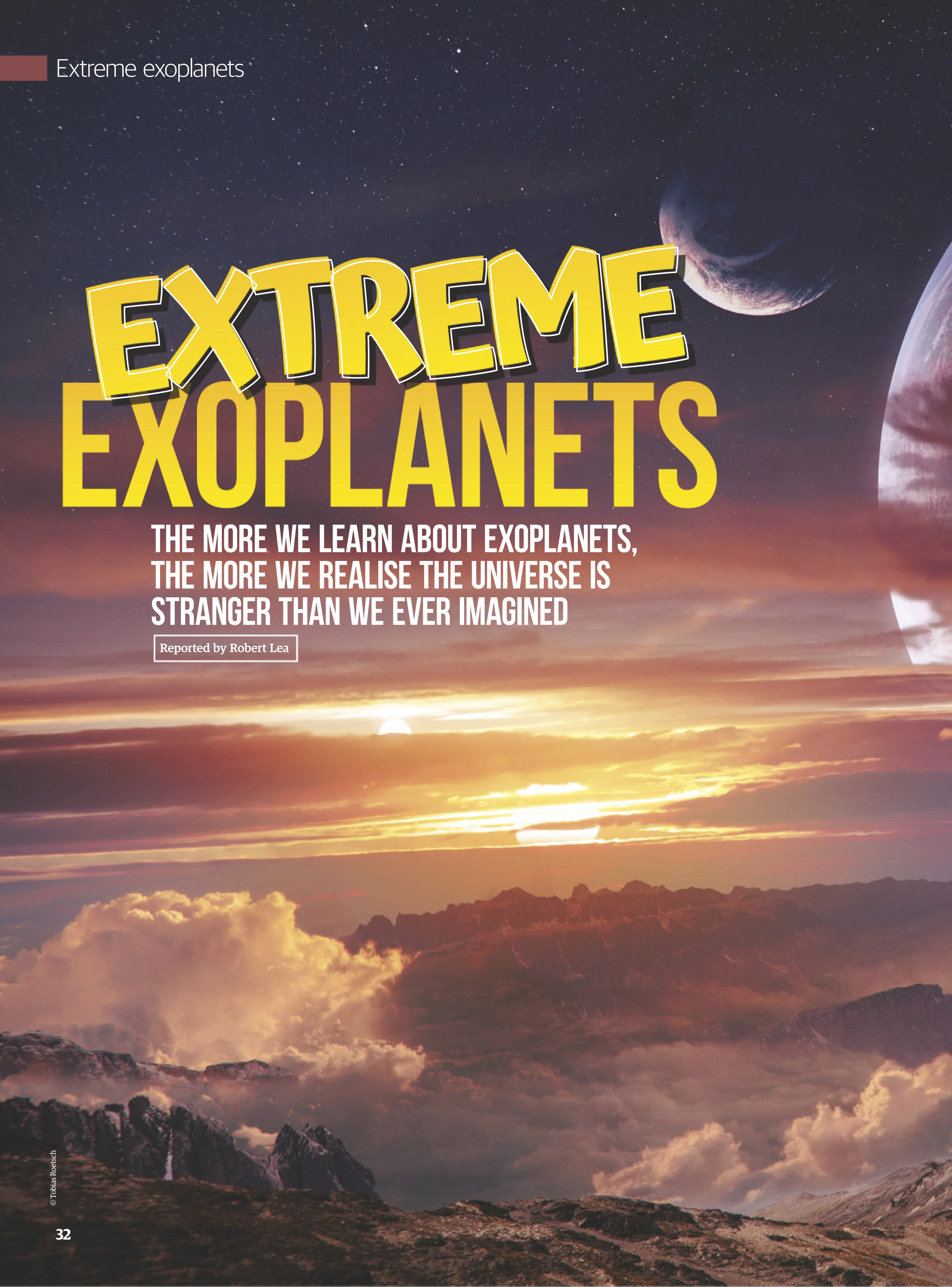


EXTREME EXOPLANETS

THE MORE WE LEARN ABOUT EXOPLANETS, THE MORE WE REALISE THE UNIVERSE IS STRANGER THAN WE EVER IMAGINED

Reported by Robert Lea

© Tobias Roetsch

It's almost hard to believe that until the early years of the 1990s, astronomers had yet to discover a planet outside the Solar System. Even though scientists were certain that planets orbited other stars, there was little evidence of other planetary systems until the discovery of two extrasolar planets - or exoplanets - orbiting the pulsar PSR B1257+12 in 1992 by Aleksander Wolszczan and Dale Frail. This initial discovery was soon followed by the observation of 51 Pegasi b - the first exoplanet discovered around a Sun-like star - in 1995, for which astronomers Michel Mayor and Didier Queloz were awarded the 2019 Nobel Prize in Physics.

Since 1995 our exoplanet catalogue has rapidly expanded. We have now confirmed over 4,400 worlds outside our Solar System, with a further 7,600 or so suspects waiting to be classified. As our observation methods improve, this discovery process has only really just begun. And later this year, the James Webb Space Telescope (JWST) will finally launch, with part of its mission dedicated to searching for exoplanets.

A surprising factor has started to present itself as we learn more about worlds outside the Solar System: the universe is weird. Really weird. From worlds that rain iron and glass to diamond worlds and planets that have escaped the grip of their parent stars, our burgeoning exoplanet catalogue demonstrates that our own Solar System is reassuringly boring.

THE PLANET THAT GREW A SECOND ATMOSPHERE

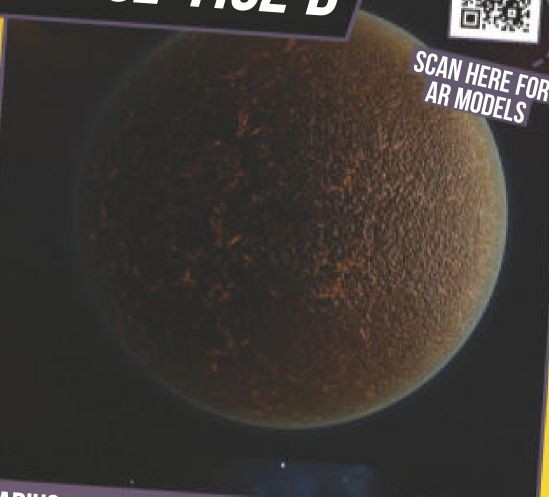
Gliese 1132 b is similar to Earth in a striking number of ways. Its radius is only slightly larger, as is its mass. Even its age - 4.5 billion years old - is similar to that of our planet. But this world does have one striking difference: it orbits much closer to its red dwarf parent star, completing an orbit in just 1.6 Earth days. This proximity results in Gliese 1132 b experiencing a much higher surface temperature than our planet, at 256 degrees Celsius (493 degrees Fahrenheit), with the intense radiation stripping the atmosphere.

But astronomers have recently discovered that something extraordinary is happening on Gliese 1132 b. The gravitational influence of its host star creates intense tidal forces that squeeze and stretch the planet. This 'flexing' gives rise to violent volcanic activity and causes gases to rush to the world's surface.

These gases are building the world a second atmosphere. While this is exciting in itself, being the first time astronomers have ever spotted anything like this, the 'regrown' atmosphere, due to its origin, also provides astrogeologists with a unique opportunity to study the interior chemical composition of an exoplanet by proxy.

GLIESE 1132 B

SCAN HERE FOR AR MODELS



RADIUS:	~7,200 KILOMETRES (4,474 MILES)
MASS:	$\sim 9.9 \times 10^{24}$ KILOGRAMS
TYPE:	TERRESTRIAL ROCKY PLANET
DISTANCE FROM EARTH:	41 LIGHT YEARS
PARENT STAR TYPE:	RED DWARF

© Nicholas Forder

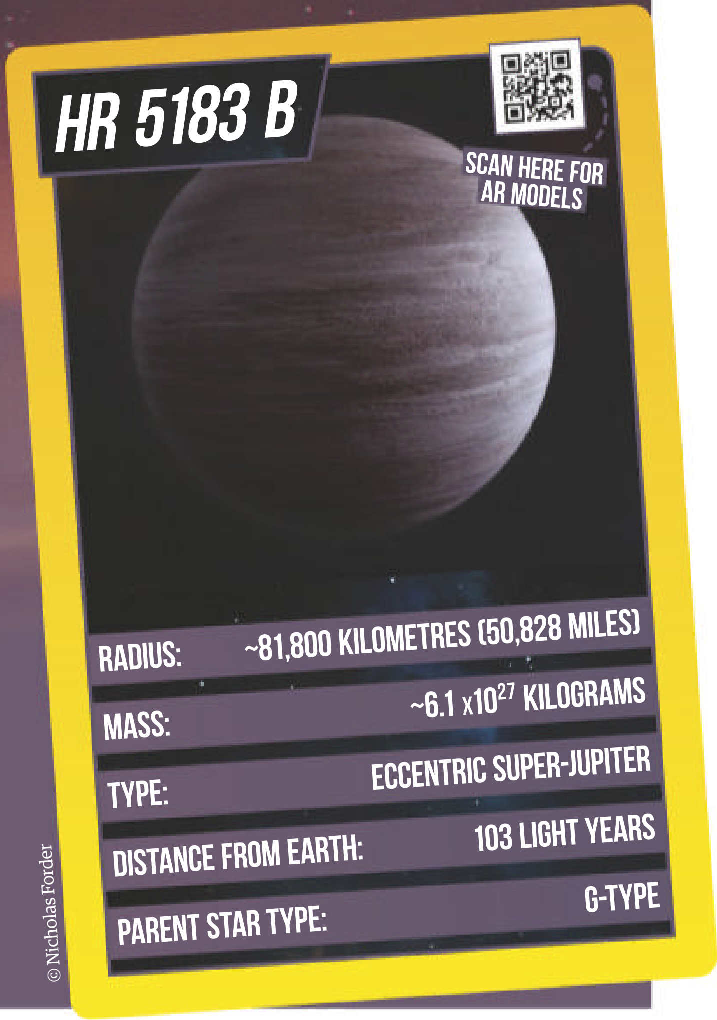
THE ORBITAL ODDBALL

HR 5183 b – a 'super-Jupiter' three times the mass of the Solar System's largest planet – is unique as its orbit is highly eccentric. While most planets trace out an almost-circular orbit, this gas giant traces out an egg-shaped orbit around its parent star HR 5183.

Astronomers discovered the exoplanet from the tiny wobble its gravity causes upon its parent star, which in turn causes a dip in brightness. The process took a staggering 20 years of observations with three telescopes, including Hawaii's W. M. Keck Observatory. Despite this long period of observation, we are yet to see the world complete a full orbit, with researchers estimating that this could take between 45 and 100 Earth years – probably 74 years.

If HR 5183 b was to follow its orbit in the Solar System, it would pass closer to the Sun than Jupiter, then move to the outer edges of our planetary system, swinging past Neptune. Highly eccentric orbits such as this have been observed before, but normally by planets and other objects that are much closer to their host stars.

If HR 5183 b's loose association with its parent star is something of a surprise, some worlds have gone to even further extremes, disassociating with their parent stars entirely to wander the universe alone.



HR 5183 B

SCAN HERE FOR AR MODELS

RADIUS:	~81,800 KILOMETRES (50,828 MILES)
MASS:	~6.1 x10^{27} KILOGRAMS
TYPE:	ECCENTRIC SUPER-JUPITER
DISTANCE FROM EARTH:	103 LIGHT YEARS
PARENT STAR TYPE:	G-TYPE

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GOING ROGUE

Astronomers believe that the Milky Way could be teeming with cosmic orphans – exoplanets that have broken free of their parent stars to wander the galaxy alone. These planets are thought to form in traditional ways around stars, but are later flung away by gravitational interactions with other planets. Because exoplanets are usually spotted through the effect they have on their host stars, this makes these homeless planets almost impossible to spot. This is especially true when they are Earth-sized rocky planets. That's what makes the discovery of the rogue exoplanet OGLE-2016-BLG-1928 so special. While it isn't the first rogue planet to be discovered, it is the smallest, with other examples much similar in size to Jupiter.

The world was spotted in late 2020 using a technique called gravitational microlensing, the deflection and focusing of light from a distant star as an object passes in front of it. The duration of the change in the light profiles of these distant sources increases with the mass of the intervening object. The disturbance caused by OGLE-2016-BLG-1928 lasted just 41 minutes, telling astronomers that it was the smallest rogue spotted using this method thus far.

OGLE-2016-BLG-1928

SCAN HERE FOR AR MODELS

RADIUS:	UNCERTAIN
MASS:	~1.7 x10^{24} KILOGRAMS
TYPE:	ROGUE TERRESTRIAL
DISTANCE FROM EARTH:	UNCERTAIN
PARENT STAR TYPE:	N/A

© Nicholas Forder

A SYSTEM OF HARMONY AND CHAOS

At first glance the planetary system TOI-178 may look like any other set of worlds. But a closer and more prolonged observation reveals that at least five of this system's worlds are locked in a rhythmic dance with each other. The five outer planets exist in an 18:9:6:4:3 resonance. This means that the planets align at regular intervals as they orbit their orange dwarf host star.

This complex chain of resonance likely indicates a planetary system that has remained undisturbed by gravitational interactions or collisions with other systems since its formation. That means the system could be crucial in the study of how

Above: There are six confirmed planets in the TOI-178 system, five of which are locked in a rhythmic dance aroun their star

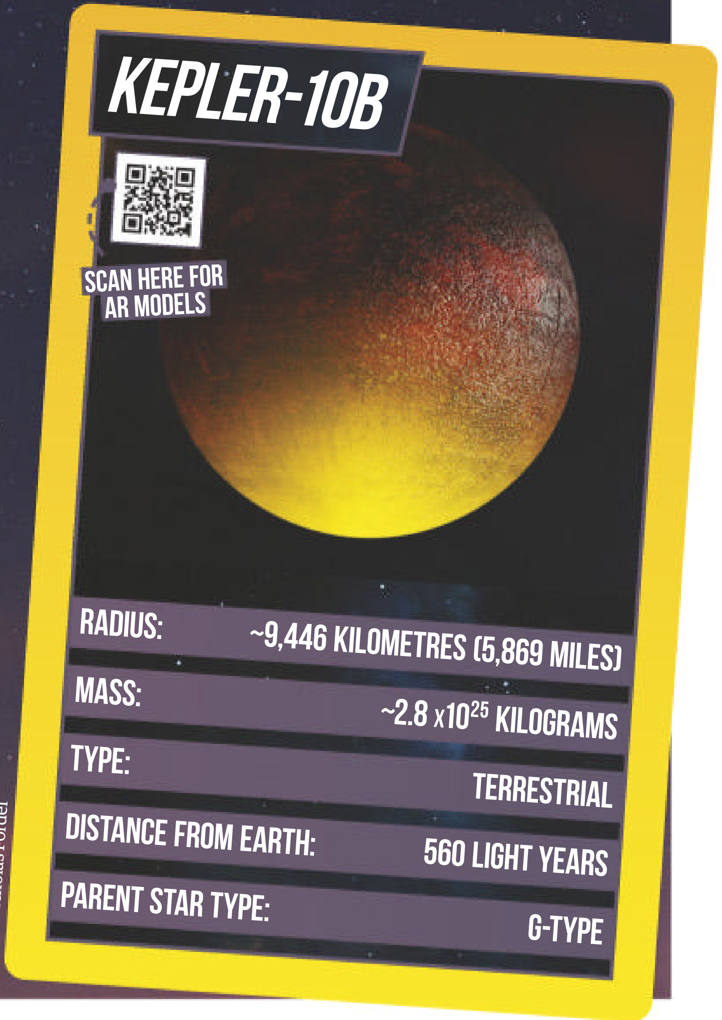
IN A GALAXY FAR, FAR AWAY...

Kepler-10b orbits close to its host star – a star similar to the Sun – at a distance that is five per cent the orbit of Mercury. This results in an orbit that takes less than a single Earth day and a surface temperature hotter than 1,300 degrees Celsius (2,372 degrees Fahrenheit).

Because Kepler-10b – discovered in 2011 by the Kepler telescope – is tidally locked to its star, it also creates molten droplets of iron and silicates. The planet's surface is likely covered with lava much hotter than that found on Earth. Because the harsh radiation from its host star has stripped away its atmosphere, these droplets on Kepler-10b won't fall on the nightside of the planet, and are instead blown clear of its surface by stellar winds, giving it a fiery tail.

Kepler-10b isn't the only lava world discovered by Kepler. In 2013 the space telescope also found the exoplanet Kepler-78b – 40 times closer to its host star than Mercury – that completes a full orbit in a matter of hours. The result is an Earth-like world dominated by lava, which has been described by astronomer Dimitar Sasselov as "an abomination".

Given their molten lava surfaces, it's little wonder that these exoplanets have been compared to Mustafar, the planet in the *Star Wars* franchise that hosts a lightsaber duel between Obi-Wan Kenobi and Anakin Skywalker. The lava of that fictional world results in hideous injuries to the young Jedi, which force him to wear the iconic black armour and breathing apparatus of Darth Vader. Perhaps when considering a world to hold a duel to the death, somewhere that offers a cooler climate may be advisable.


SCAN HERE FOR AR MODELS

KEPLER-10B

RADIUS:	~9,446 KILOMETRES (5,869 MILES)
MASS:	~2.8 $x10^{25}$ KILOGRAMS
TYPE:	TERRESTRIAL
DISTANCE FROM EARTH:	560 LIGHT YEARS
PARENT STAR TYPE:	G-TYPE

© Nicholas Forder

> "THE RESULT IS AN EARTH-LIKE WORLD DOMINATED BY LAVA"

planetary systems form and evolve.

Yet where we find order in the cosmos, there is often chaos. The compositions of the planets that make up the TOI-178 system don't display the harmony exhibited by their motion. Next to a dense terrestrial Earth-like world is a 'puffed-out' low-density planet, followed by an exoplanet with a density similar to that of Neptune.

© ESA

SCAN HERE FOR AR MODELS

THE TOI-178 SYSTEM

RADIUS:	~7,350 KILOMETRES (4,567 MILES) TO ~18,305 KILOMETRES (11,374 MILES)
MASS:	~9 $x10^{24}$ TO ~4.6 $x10^{25}$ KILOGRAMS
TYPE:	SUPER-EARTHS AND MINI-NEPTUNES
DISTANCE FROM EARTH:	205 LIGHT YEARS
PARENT STAR TYPE:	K-TYPE ORANGE DWARF

© Nicholas Forder

A WORLD OF FIRE AND ICE

Upsilon Andromedae b is another exoplanet that is probably tidally locked to its host star, completing an orbit in just under five days. What makes this planet – which was previously known as Saffar – an extreme world is the radical difference in temperature between its dayside and nightside. While the dayside experiences temperatures as high as 1,600 degrees Celsius (2,912 degrees Fahrenheit), the nightside is considerably cooler, reaching temperatures as low as -20 degrees Celsius (-4 degrees Fahrenheit). Passing the hemisphere of this world could be considered equivalent to jumping into a volcano.

While this is by no means the only tidally locked hot Jupiter, the others we have discovered don't seem to feature such radical disparities in temperature. The reason this exoplanet experiences such a radical difference in temperature could be due to the tremendous size of its parent star Upsilon Andromedae A, or the fact that the star possesses a hotspot almost directly 'overhead' of the exoplanet.

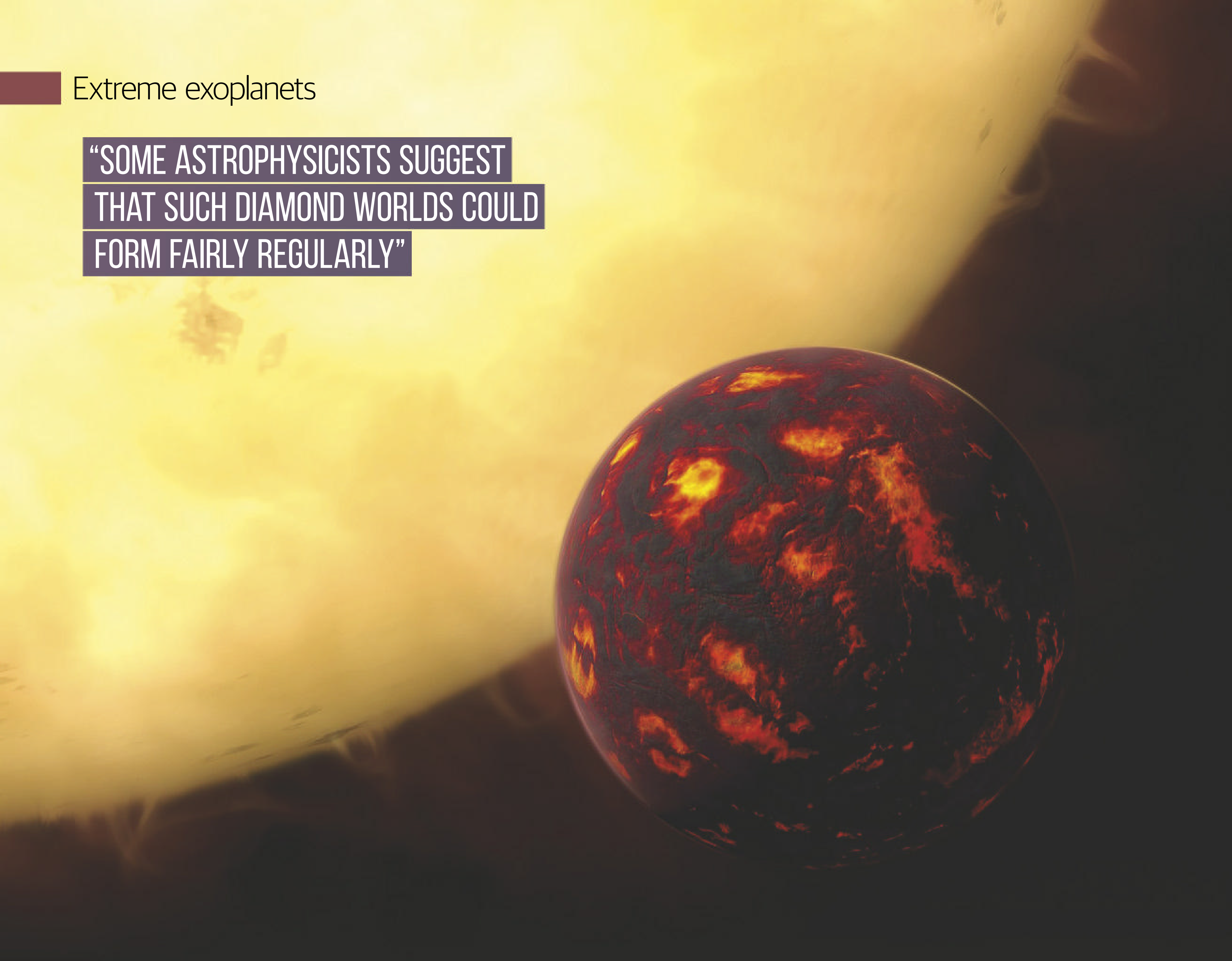
SCAN HERE FOR AR MODELS

UPSILON ANDROMEDAE B

RADIUS:	~87,390 KILOMETRES (54,300 MILES)
MASS:	~1.3 $x10^{27}$ KILOGRAMS
TYPE:	HOT JUPITER
DISTANCE FROM EARTH:	44 LIGHT YEARS
PARENT STAR TYPE:	BINARY WITH AN F-TYPE AND A SMALLER RED DWARF

© Nicholas Forder

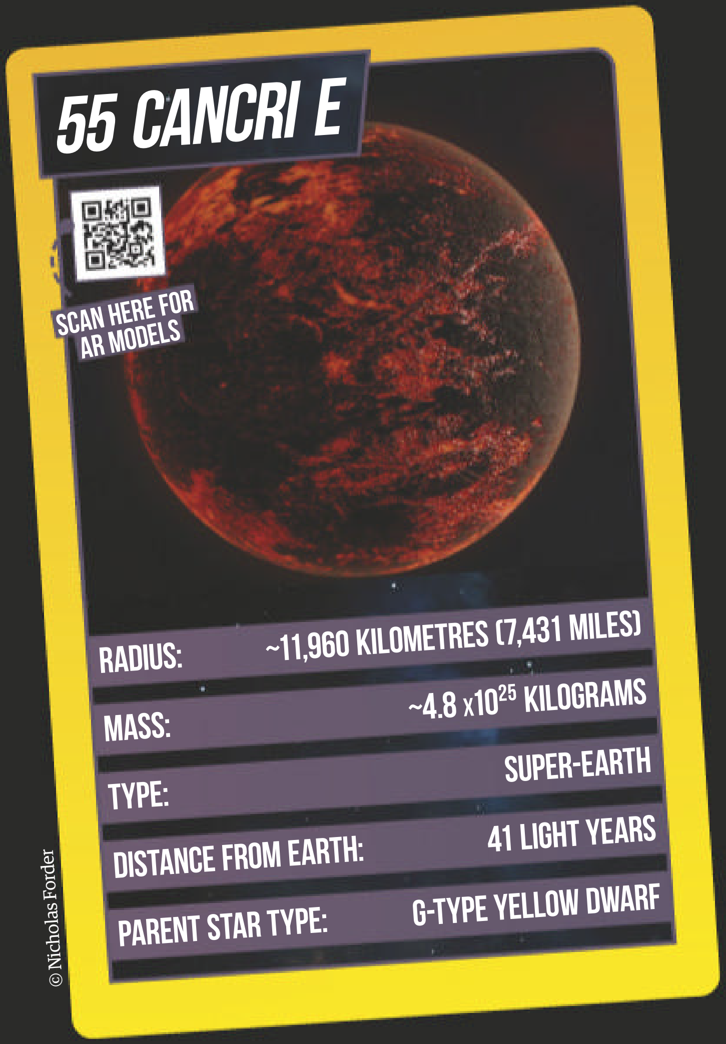
> “SOME ASTROPHYSICISTS SUGGEST THAT SUCH DIAMOND WORLDS COULD FORM FAIRLY REGULARLY”



Above: The molten-hot super-Earth 55 Cancri e could be the most valuable object in the universe if theories that it is composed of diamond are correct

© ESA

THE UNIVERSE’S MOST VALUABLE EXOPLANET



55 CANCRI E

SCAN HERE FOR AR MODELS

RADIUS:	~11,960 KILOMETRES (7,431 MILES)
MASS:	$\sim 4.8 \times 10^{25}$ KILOGRAMS
TYPE:	SUPER-EARTH
DISTANCE FROM EARTH:	41 LIGHT YEARS
PARENT STAR TYPE:	G-TYPE YELLOW DWARF

© Nicholas Forder

Another planet that orbits close to its host star - taking under 18 hours to complete an orbit - 55 Cancri e is also inhospitably hot, reaching temperatures as high as 2,300 degrees Celsius (4,172 degrees Fahrenheit). But what really sets this world apart is its composition, which makes the exoplanet formally known as Janssen perhaps the most conventionally valuable object in the universe.

The fact that 55 Cancri e is twice the size of Earth but has around eight times the mass led astronomers to propose that this super-Earth could be composed of highly pressurised carbon in the form of graphite and diamond, mixed with some iron and other elements.

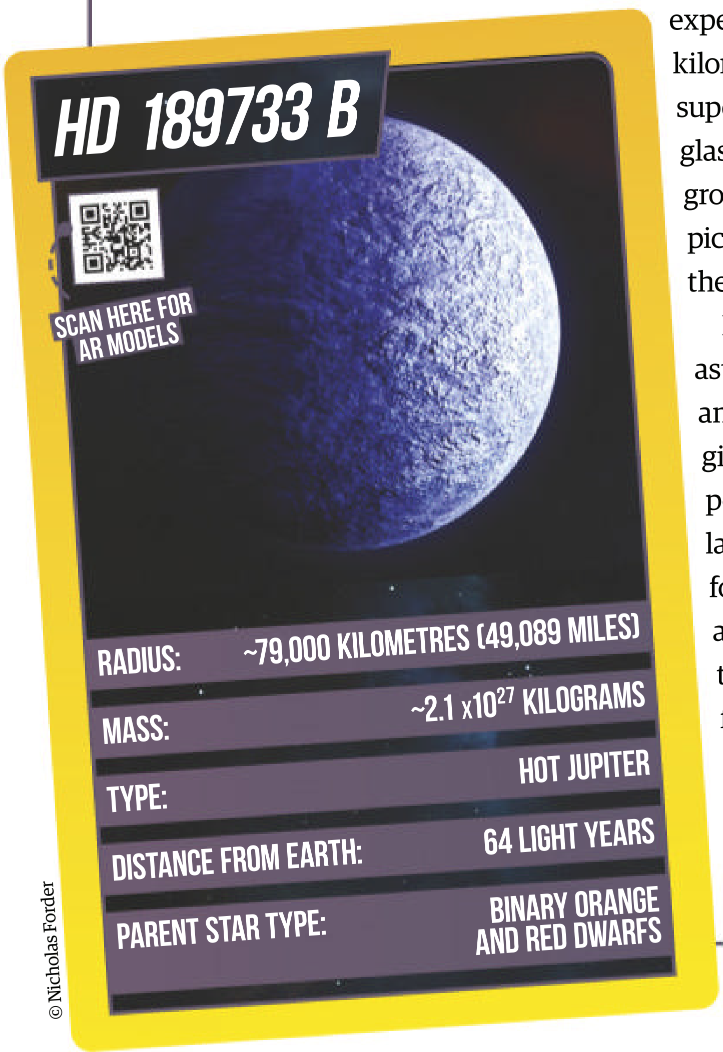
The estimated value of 55 Cancri e is £19.6x10^{30} (\$26.9x10^{30}). That’s 384 quadrillion times more than Earth’s entire Gross Domestic Product (GDP), which was valued at £51 trillion ($70 trillion) in 2011. Some astrophysicists suggest that such diamond worlds could form fairly regularly when protoplanetary dust clouds that contain high ratios of carbon collapse to form planets.

The idea that 55 Cancri e is made of diamond has been challenged since the exoplanet was first discovered in 2004, moving in and out of favour and proving diamonds may not be forever. Yet despite all these extreme worlds, the most extraordinary exoplanets may still be out there for us to discover, and they may exist in systems we have never encountered before.

RAINING MOLTEN GLASS

From space HD 189733 b appears to be a beautiful and tranquil world, resembling a giant, glassy blue marble. With exoplanets appearances can be deceptive, and this is definitely the case for this gas giant planet, which completes an orbit of its star in just 2.2 days. In fact, its beautiful blue hue arises from its deadly weather, particularly the molten glass rains that pelt the planet's surface. Yet this isn't the extent of the planet's almost-maniacal weather conditions. The exoplanet – discovered in 2005 by both the Chandra X-ray Observatory and XMM-Newton X-ray telescope – also experiences winds of around 9,000 kilometres (5,592 miles) per hour. These supersonic winds cause the exoplanet's glass rains to arc sideways towards the ground rather than just falling, also picking up silicate particles and turning them into microscopic projectiles.

HD 189733 b isn't just interesting to astronomers because of its unusual and hazardous weather, though. The giant exoplanet has been observed to possess an atmosphere that is much larger than scientists would expect for such a world. This extended atmosphere works to catch more of the radiation HD 189733 b receives from its parent stars thanks to its perilously close orbit, meaning the gas giant experiences temperatures as high as 930 degrees Celsius (1,706 degrees Fahrenheit).


HD 189733 B
SCAN HERE FOR AR MODELS

RADIUS: ~79,000 KILOMETRES (49,089 MILES)
MASS: ~2.1 x10^{27} KILOGRAMS
TYPE: HOT JUPITER
DISTANCE FROM EARTH: 64 LIGHT YEARS
PARENT STAR TYPE: BINARY ORANGE AND RED DWARFS

© Nicholas Forder

THE EXOPLANET THAT RAINS MOLTEN IRON

Spotted in 2013 and further investigated by the Echelle SPectrograph for Rocky Exoplanets and Stable Spectroscopic Observations (ESPRESSO) instrument on the Very Large Telescope in 2020, WASP-76b is a planet that's tidally locked to its parent star BD+01 316. This means that one side of the planet permanently faces the star, causing scorchingly hot temperatures of around 2,500 degrees Celsius (4,532 degrees Fahrenheit) – hot enough to vaporise iron.

The star-facing side of WASP-76b is roasted by radiation that is thousands of times more intense than Earth receives from the Sun, while the side that faces away from the F-type star experiences perpetual night. Yet even though the 'dayside' of the planet experiences hellish temperatures, that doesn't mean that conditions on the 'nightside' are a walk in the park. The side of WASP-76b that faces away from the star is cooler by at least 1,000 degrees Celsius (1,832 degrees Fahrenheit), but this means that when iron vapour is carried across to the other side by powerful winds it cools, forming liquid droplets. These droplets of molten iron then fall, bombarding the cooler side of the planet.

WASP-76B
SCAN HERE FOR AR MODELS

RADIUS: ~128,000 KILOMETRES (79,536 MILES)
MASS: ~1.7 x10^{27} KILOGRAMS
TYPE: HOT JUPITER
DISTANCE FROM EARTH: 634 LIGHT YEARS
PARENT STAR TYPE: F-TYPE

© Nicholas Forder

BLANETS
SCAN HERE FOR AR MODELS

RADIUS: UNKNOWN
MASS: UNKNOWN
TYPE: UNKNOWN
DISTANCE FROM EARTH: UNKNOWN
PARENT STAR TYPE: SUPERMASSIVE BLACK HOLES

© Nicholas Forder

BLACK HOLES' EXTREME EXOPLANETS

Planets form from the gravitational collapse of over-dense areas of protoplanetary clouds of gas of dust, and supermassive black holes at the heart of active galactic nuclei (AGN) sit at the centre of massive, churning discs of such materials. At the moment there is no evidence that such black-hole-orbiting planets – or 'blanets' – actually exist, but recent research modelling the dynamics of these discs of gas and dust suggests that under certain conditions planet formation should occur in such regions. Should such processes occur, blanets would form much farther out from supermassive black holes than most planets do from their parent star – so distant, in fact, that it could take a million years for such a world to complete an orbit.

Radiation from the AGN could help provide a constant supply of fresh material for blanet formation, and the result of this could be runaway formation, meaning blanets could reach sizes much more titanic than 'regular' exoplanets. Blanets would be less likely to share similarities with the planets of the Solar System, with whole new classes of astronomical objects beyond gas giants and terrestrial worlds to investigate.

With the nearest AGN existing beyond the limits of current exoplanet investigations, the potential discovery of blanets may have to wait. Until then astronomy will provide a cavalcade of exoplanet discoveries that challenge our growing understanding of the universe and redefine our place within it.

NASA WANTS TO CHANGE THE WAY IT PROTECTS ASTRONAUTS FROM RADIATION

With long-term missions in the pipeline, safety is paramount

Reported by Rahul Rao

Astronauts face constant radiation as particles streaming off the Sun and high-energy cosmic rays bombard their bodies. Left unchecked, radiation can trigger all sorts of health issues, most notably boosting the danger of developing cancer. When NASA plans missions, the agency uses a radiation exposure cap to determine how long astronauts can stay in space. But that cap isn't equal for all astronauts.

NASA calculates the cap based on a risk estimate. The limit is the amount of total exposure that would give an astronaut a three per cent higher chance of dying of cancer. However, susceptibility to the types of cancer that radiation can cause varies with age and reproductive organs, so the limit doesn't allow equal time in space. NASA's women can't spend as much time in orbit as men, and younger astronauts can't stay up as long as their older counterparts, who don't have as many years left for cancer to develop.

NASA has previously considered changing this system to a cap that would limit all astronauts' exposure to the risk limit as applied to the most vulnerable: a 35-year-old woman. Now a committee of the National Academies of Sciences, Engineering and Medicine (NAS) has unveiled a report that supports NASA's proposal.

In hard units, that's a total of 600 millisieverts over a career with the agency. For comparison, a single chest X-ray at your doctor's office gives you around 0.1 millisieverts, and you pick up around three millisieverts every year from Earth's natural background radiation. Workers near Chernobyl's ground zero in 1986 were showered with 6,000 millisieverts. Meanwhile, a six-month stay on the International Space Station exposes an astronaut to between 50 and 120 millisieverts. However, more distant destinations like Mars carry greater exposures. In effect, the proposed limit would expose younger astronauts and women to comparatively riskier

> "WE AGREED THAT THE BEST THING TO DO WAS SET IT ACCORDING TO THE STANDARD FOR THE MOST VULNERABLE POPULATION"
>
> CAROL SCOTT-CONNER

© NASA

Left: Invisible radiation is bombarding astronauts at all times

amounts of radiation and reduce the amount of time that older astronauts and men can spend in orbit.

NASA's radiation standards were last updated in 2014. "A lot has changed since then, in terms of our understanding of radiation biology," said Dr Carol Scott-Conner, a professor of surgery at the University of Iowa, who was on the NAS committee. But the suggested change isn't supported universally. "I think this change is problematic," said Francis Cucinotta, a radiation biologist at the University of Nevada, Las Vegas. He says it's akin to playing Russian roulette with female astronauts, placing them at extra risk from radiation exposure. But Scott-Conner disagrees: "We agreed that the best thing to do was set it according to the standard for the most vulnerable population, which is a 35-year-old woman," she said. Furthermore, she said that NASA's exposure limits are significantly lower than those of other space agencies.

However, Cucinotta thinks that focusing solely on cancer risk ignores other problems linked to radiation, such as heart disease and cognitive issues. He thinks NASA ought to look at more data before the agency makes comprehensive changes.

STAR PROFILE

POLARIS

The more we find out about our guiding star, the more it fascinates us

Polaris, the North Star, is a single point in the night sky which the entire consortium of stars appears to revolve around. Despite being one of the most well-known stars in the sky, Polaris continues to confuse scientists. We still don't know for sure how old the star is, or even exactly how far away it is from Earth.

The yellow supergiant is a Cepheid variable star, which means its brightness fluctuates by less than a tenth of a magnitude every few days. A common misconception is that Polaris is the brightest star in the sky, but this position is actually held by Sirius, with Polaris only ranking 48th in terms of luminosity.

Since Polaris isn't incredibly bright or visible to us, how has it been our famous guiding star, escorting travellers for centuries? The answer is its location. Polaris is our one constant in the perpetually moving night sky, remaining in almost the exact same position above the northern horizon all year round. In Mongolian mythology it's considered to be the peg that holds the world together, and in Norse mythology it was the end of a spike around which the sky rotates.

No matter where you find yourself in the Northern Hemisphere, if you locate Polaris, you know you're facing north. If you want to take navigation one step further, you can measure the distance between Polaris and the horizon to discover a second valuable data point: your latitude. If you were to stand at the North Pole, Polaris would appear almost directly overhead - the star is slightly offset from the true north celestial pole by less than a degree.

It's hard to believe that such a prominent sight in our night sky has not always held its prime pole position. Around 4,600 years ago when the ancient Egyptians were building the Great Pyramid of Giza, the star Thuban in the constellation of Draco would have been the closest star to the North Pole. And in about 12,000 years, Vega will replace Polaris as our pole star. This celestial switch-up is due to the slight 'drifting' of Earth's axis, known as precession. Akin to the wobble of a spinning top, Earth experiences tidal forces caused by the gravitational effects of the Sun and Moon. This wobble results in either the Northern or Southern Hemisphere being closest to the Sun, and the cycle of axial precession lasts about 25,771 years.

Polaris is currently still moving closer to Earth's North Pole, and on 24 March 2100 it will be as close to the North Pole as it'll ever come at just 27.4 arcminutes - slightly less than the Moon's apparent diameter. At least for now we can relax knowing our North Star Polaris is going to be with us for many more years to come - and it won't be alone. The single point of light we see as Polaris from Earth is actually beaming from a triple star system. Polaris AB and Polaris B are yellow-white dwarf stars that lie approximately 3.2 billion kilometres (2 billion miles) and 400 billion kilometres (249 billion miles) away from primary star Polaris A respectively.

DID YOU KNOW?

POLARIS HAS ONLY BEEN THE NORTH STAR FOR ABOUT 2,000 YEARS

> "NO MATTER WHERE YOU FIND YOURSELF IN THE NORTHERN HEMISPHERE, IF YOU LOCATE POLARIS, YOU KNOW YOU'RE FACING NORTH"

© NASA

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18+

WHAT IS AVAXHOME?

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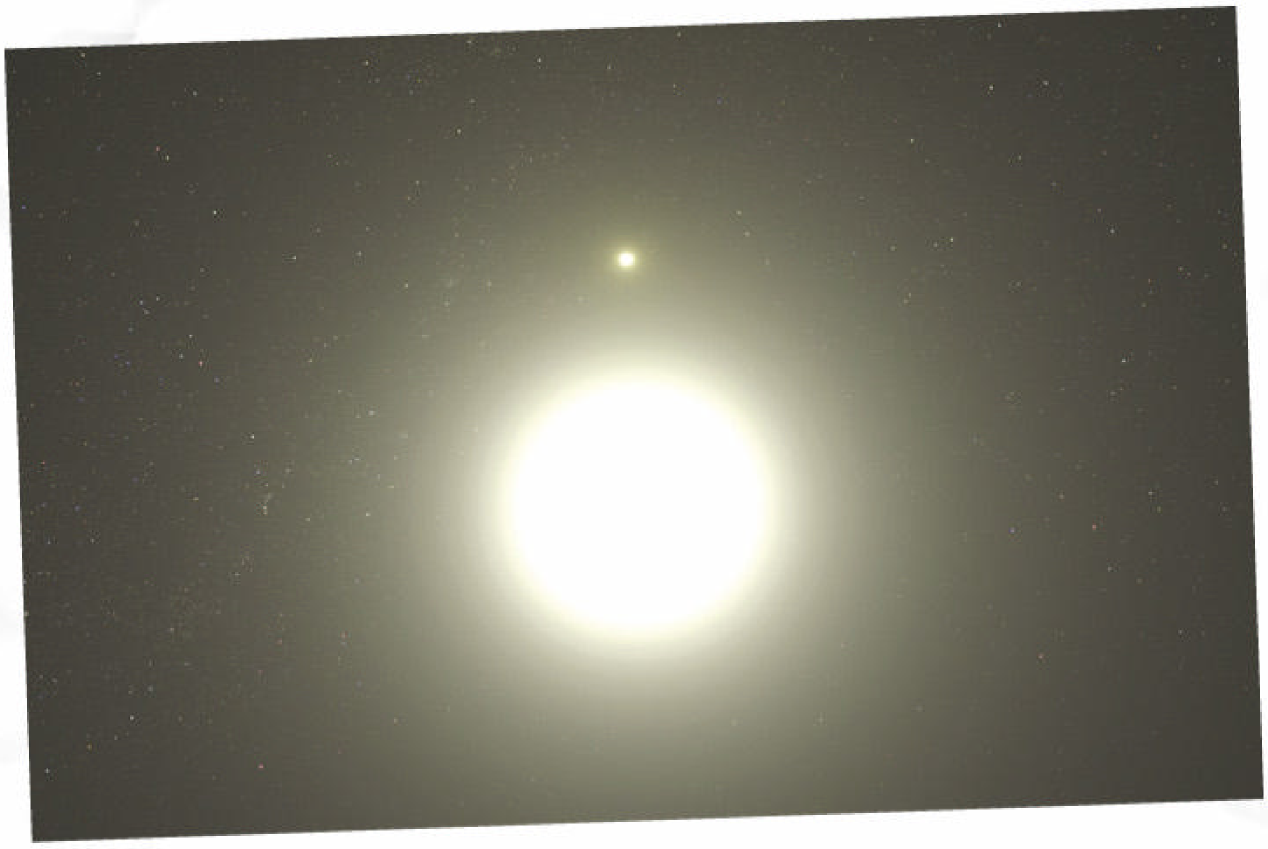
NEWS FROM POLARIS

Polaris continues to puzzle scientists

There are various ways to calculate the mass of a star. One is based on stellar evolution models, using a star's brightness, colour and rate of pulsation to calculate how big and bright it is, as well as infer what stage of its evolution it's in. Using this method, Polaris is calculated to be about seven times the mass of our Sun. But other methods have given different results.

Because scientists know that Polaris is part of a binary system with its companion star Polaris B, completing an orbit every 26 years or so, they apply Newton's law of gravity to measure the mass of the two stars. This particular method puts Polaris at just three-and-a-half times the mass of our Sun, a stark difference to the stellar evolution models.

Scientists are also baffled by how Polaris B appears to be older than Polaris, which is most unusual for binary star systems, where both stars are usually a similar age. These uncertainties stem from the fact that Polaris is the closest Cepheid variable to Earth, and its location makes it fairly tricky to study.



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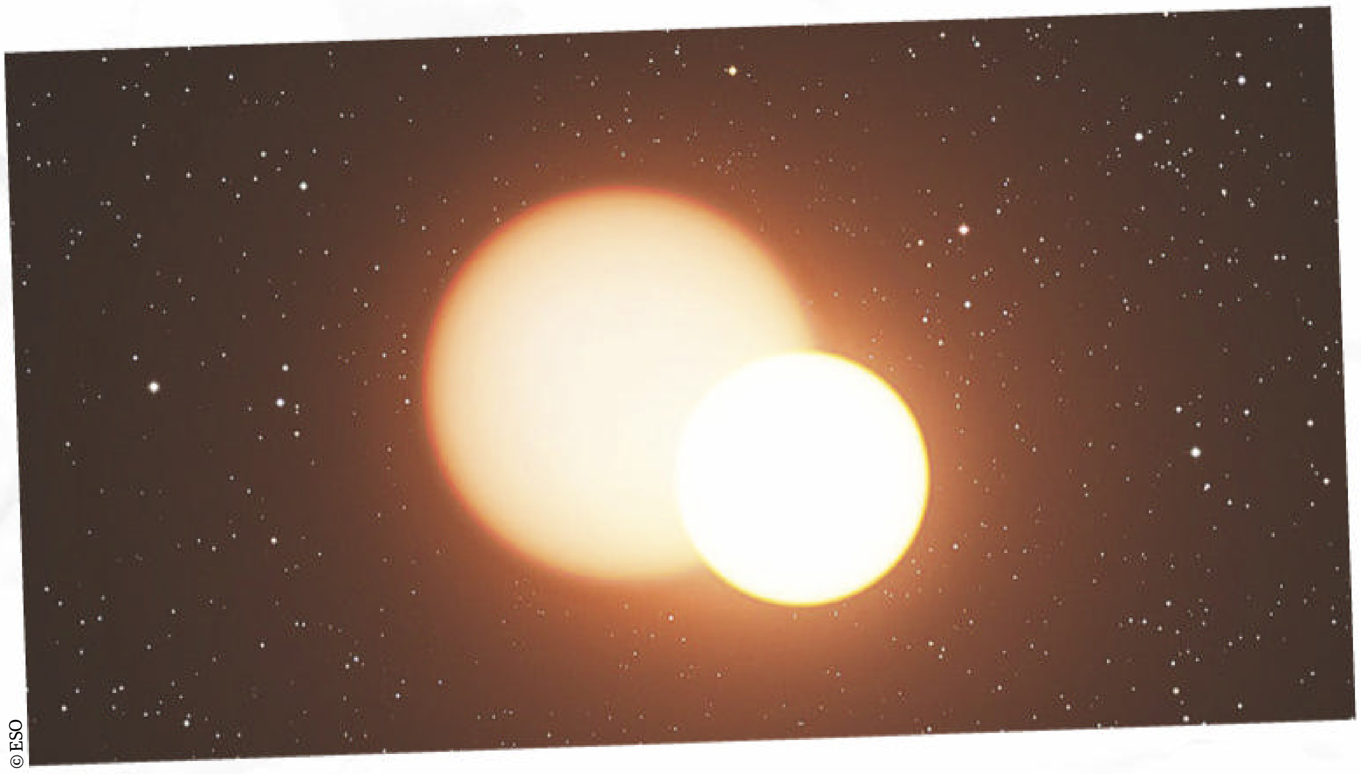

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Polaris is getting brighter

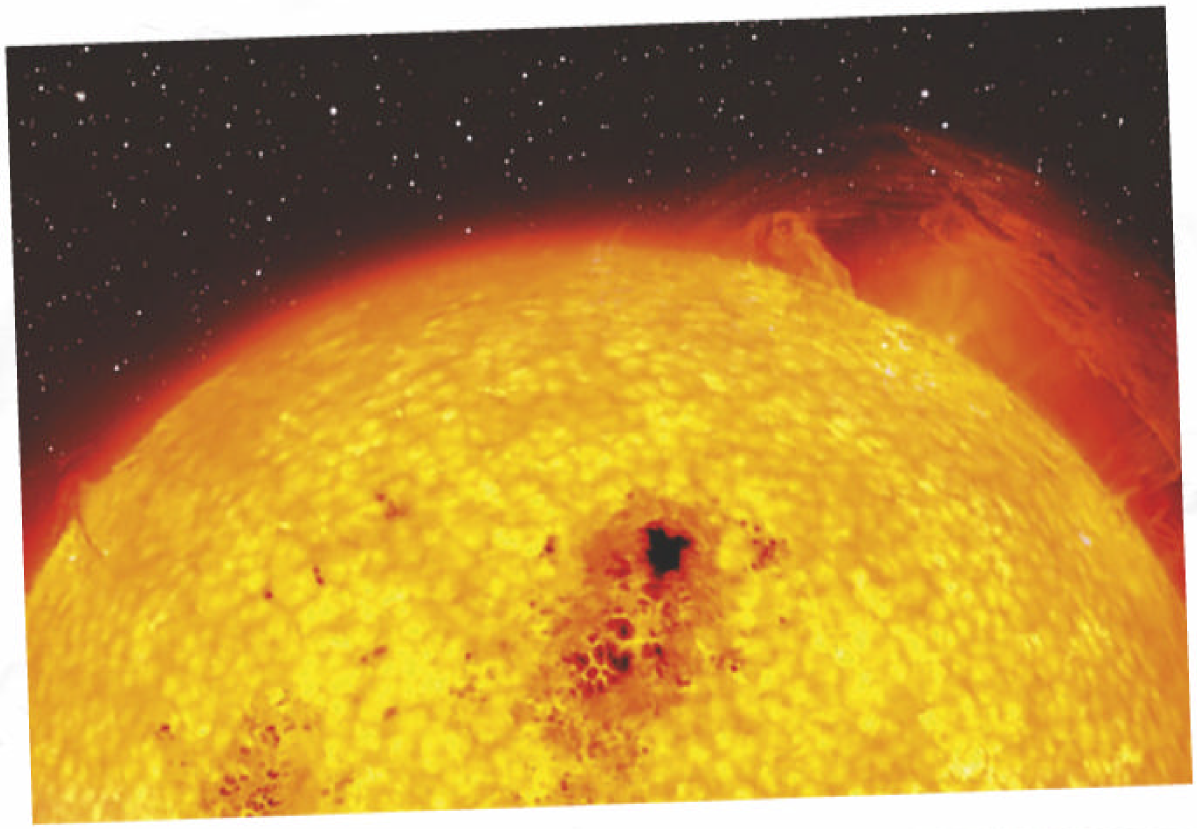
In 2014, astronomers studying Polaris announced that the Cepheid variable star's brightness was on the rise. The increase in brightness is considered to be relatively dramatic when compared to historical records. These records show that Polaris could be at least two-and-a-half times brighter today compared to 200 years ago. But when modern interpretation estimates are used on the historical data, Polaris could even be four-and-a-half times brighter than it was in ancient times.

Brightening and dimming is all part and parcel of Cepheid variable stars. However, the rate at which Polaris' brightness is changing is unusual. The adjustments in the star system's brightness are about 100 times greater than predicted by astronomers, and nobody really knows why.

Polaris may be shrinking

A 2012 study suggested Polaris may be wasting away, releasing an Earth's mass of gas every year. As Polaris is a Cepheid variable, its brightness fluctuates roughly over a four-day cycle. This is caused by physical changes within the star and the periodic expansion and contraction of the surface gas layers. The core of the star remains the same size, but the outer envelope expands and contracts, resulting in various degrees of brightness. Looking at measurements of Polaris' pulsation from historical records to present day, scientists believe that the pulse of Polaris is slowing by about four-and-a-half seconds every year.

This change in pulsation rate suggests that the structure of the star is changing. If the star is – as scientists presume – an older star fusing helium in its core, the change in pulsation is too fast to match standard models of stellar evolution. Once again, Polaris is baffling scientists. To account for this abnormally fast decrease in pulsation rate, it's been suggested that Polaris is also losing mass. A loss of stellar mass would resolve such discrepancies and explain why the star's pulsation rate is slowing, while also agreeing with standard stellar evolution theory.



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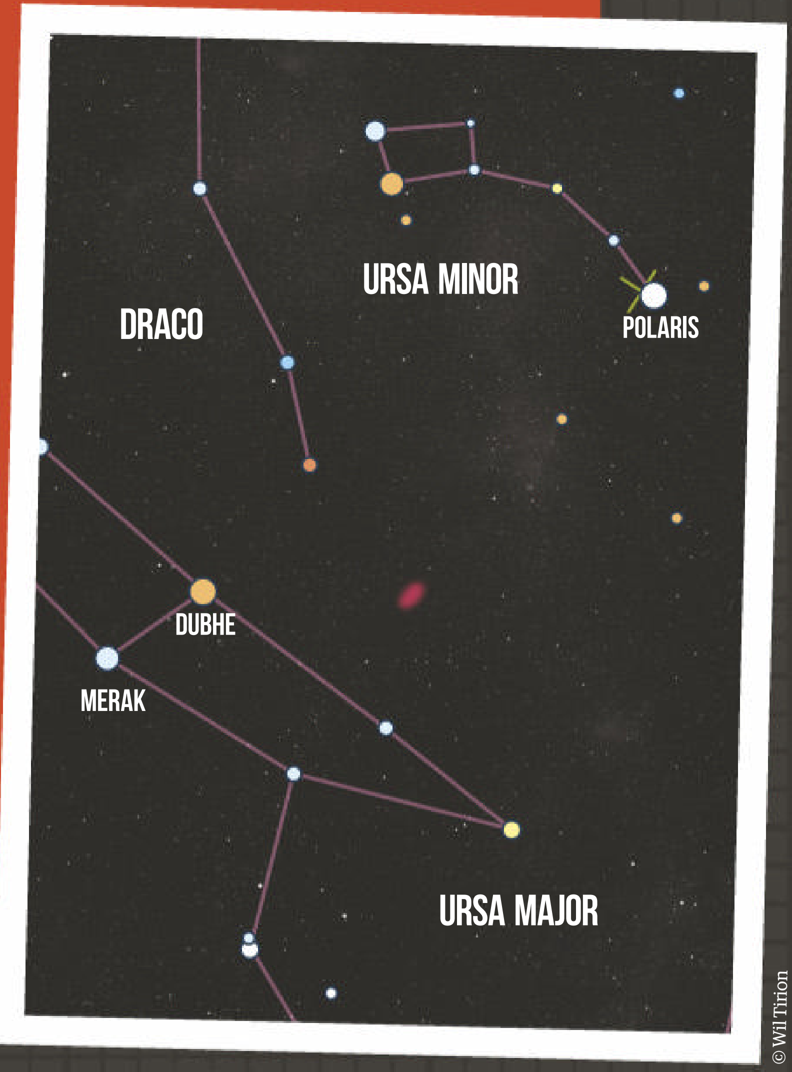
HOW TO LOCATE POLARIS IN THE NIGHT SKY

Polaris is visible to the naked eye, but you need to be in the Northern Hemisphere to see it. First you need to look for the famous Big Dipper asterism, situated in Ursa Major (the Greater Bear). In this constellation you can find two stars called Dubhe and Merak that will point you in the right direction. By drawing a line through these two stars and following the line for about five times the distance between the stars, you will soon find yourself staring straight at Polaris. The Big Dipper will appear to 'rotate' around Polaris throughout the night in a counterclockwise direction, but the two pointer stars will always guide you straight to our North Star.

Polaris is the brightest star in the constellation of Ursa Minor (Lesser Bear). It can be seen right at the end of the bear's long tail. However, Ursa Minor is hard to spot, which can make finding Polaris more difficult. Locating Polaris via the pointer stars can also help you see Ursa Minor.



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POLARIS BY NUMBERS

434
LIGHT YEARS
The distance between Earth and Polaris, though the exact distance is debated

5,700°C
Estimated surface temperature of Polaris

119
Number of days it takes for Polaris to rotate once on its axis

4.5
SECONDS
The rate at which Polaris' pulsation could be slowing every year

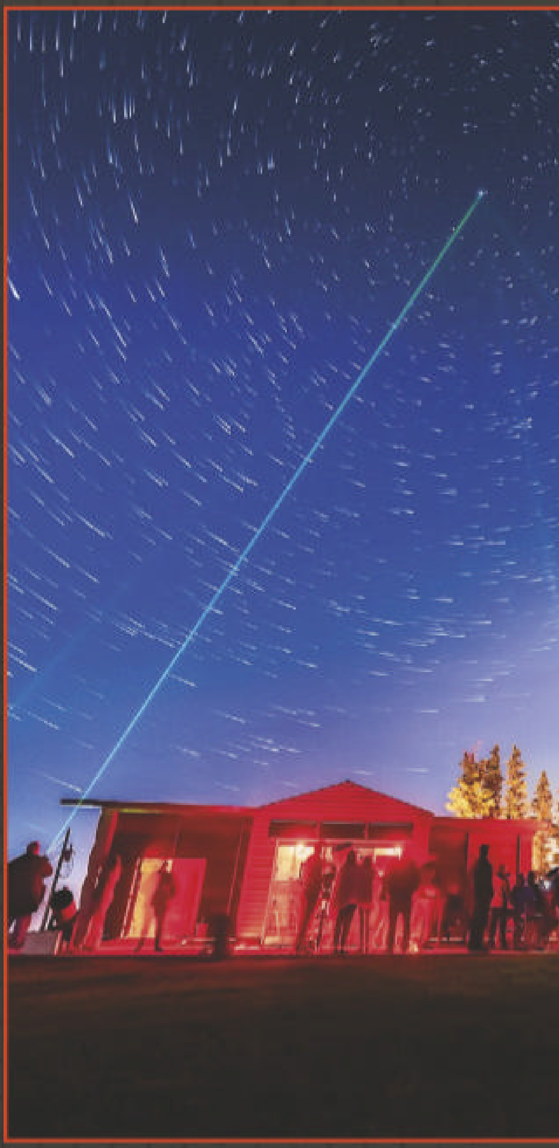
3.2
BILLION KILOMETRES
The distance between Polaris A and Polaris AB

400
BILLION KILOMETRES
The distance between Polaris A and Polaris B

4,000x
How much brighter Polaris is compared to the Sun

DEBUNKING MYTHS ABOUT POLARIS

- **Polaris is the brightest star in the sky**
  It's the 48th-brightest star in the sky. Sirius is the brightest.
- **Polaris has been and will always be our pole star**
  Due to Earth's 'wobbling' axis, other stars have held the position of pole star in the past and will do so in the future.
- **Polaris has the same constant brightness**
  It's a Cepheid variable star, and therefore varies in brightness, but this cannot be detected with the naked eye.
- **Polaris doesn't move**
  To the naked eye Polaris appears to remain fixed in the sky. However, the star does make its own tiny circle around the north celestial pole every day because the North Star is offset ever so slightly – about three-quarters of a degree – from the celestial north.



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> "IT CAN BE SEEN RIGHT AT THE END OF THE BEAR'S TAIL"

©NOIRLab/NSF/AURA

NEWLY FOUND MEGA COMET MAY BE THE LARGEST SEEN IN RECORDED HISTORY

The comet is truly a behemoth, beating other known comets thousandfold

Reported by Elizabeth Howell

A giant comet found far out in the Solar System may be 1,000 times more massive than a typical comet, making it the largest ever found in modern times. Officially designated on 23 June, it's called C/2014 UN271, or Bernardinelli-Bernstein after its discoverers, University of Pennsylvania graduate student Pedro Bernardinelli and astronomer Gary Bernstein.

Astronomers estimate this icy body has a diameter of 100 to 200 kilometres (62 to 124 miles), making it about ten times wider than a typical comet. This estimate is quite rough, however, as the comet remains far away from Earth, and its size was calculated based on how much sunlight it reflects. The comet will make its closest approach to our planet in 2031, but will remain at quite a distance even then.

"We have the privilege of having discovered perhaps the largest comet ever seen - or at least larger than any well-studied one - and caught it early enough for people to watch it evolve as it approaches and warms up," Bernstein said on 25 June from the National Science Foundation's (NSF) National Optical-Infrared Astronomy Research Laboratory, or NOIRLab.

First spotted in archival images from the Dark Energy Survey taken in 2014, Comet Bernardinelli-Bernstein is now located at the equivalent distance of Uranus, roughly 20 astronomical units (AU) from the Sun. The comet shines at magnitude +20, making it out of reach of most amateur astronomers' telescopes; by comparison, most people can see objects of magnitude +5 with the naked eye in dark conditions. When the comet swings closer to Earth in 2031, it will still only be at 11 AU, which is a little more distant than Saturn's average orbit. Even then, amateur sky-watchers will still need to use very large telescopes to see it.

What makes Comet Bernardinelli-Bernstein so special, aside from its size, is the fact it hasn't visited the inner Solar System in 3 million years, roughly the same era that the famous human ancestor 'Lucy' was walking the Earth. The comet originated some 40,000 AU from the Sun in the Oort Cloud, which is a huge, distant region of space thought to hold trillions of comets.

The comet popped up during a scan of archival images of the Dark Energy Survey, which uses a wide-field 570-megapixel CCD imager mounted on the Víctor M. Blanco telescope at the Cerro Tololo Inter-American Observatory in Chile. The survey's main goal is mapping 300 million galaxies across a swath of the night sky, but its deep-sky observations have also yielded several comets and trans-Neptunian objects (TNOs), which are icy worlds orbiting beyond Neptune.

Bernardinelli and Bernstein spotted the comet using the National Center for Supercomputing Applications and Fermilab, identifying 800 TNOs from archival survey data. While the images of the comet didn't show a classic tail between 2014 and 2018, an independent observations from the Las Cumbres Observatory network in 2021 showed the comet now has a coma of gas and dust surrounding it. Studying the comet will not only give us more insight into how this massive object formed and evolved, but could also shed light on the early history of giant planet movements in the Solar System.

> "WE HAVE THE PRIVILEGE OF HAVING DISCOVERED PERHAPS THE LARGEST COMET EVER SEEN, AND CAUGHT IT EARLY"
> GARY BERNSTEIN

"Astronomers suspect that there may be many more comets of this size waiting in the Oort Cloud far beyond Pluto and the Kuiper Belt," the NSF stated. "These giant comets are thought to have been scattered to the far reaches of the Solar System by the migration of Jupiter, Saturn, Uranus and Neptune early in their history."

While planned cometary-observation campaigns are in their early stages, a typical big event usually gets attention from the largest telescopes in space and around the world. By 2031, several newer observatories may be online to look at Comet Bernardinelli-Bernstein. Upcoming major ground-based observatories include the NSF and Department of Energy's Vera C. Rubin Observatory, whose first light is expected in 2022; the European Southern Observatory's Extremely Large Telescope, whose first light is expected by 2025, and the Giant Magellan Telescope, which should be up and running by the late 2020s.

It's harder to predict if any spacecraft will be able to observe the comet's approach, because space missions tend to be shorter than the life spans of ground-based scopes. It's possible, however, that a future telescope or mission could be funded by 2031 for comet observations that are not yet approved or even planned. The major space agencies may also task existing spacecraft across the Solar System to look at Comet Bernardinelli-Bernstein, as happened near Mars in 2014 when Comet Siding-Spring zoomed past the Red Planet.

NASA's James Webb Space Telescope is scheduled to launch in late 2021 for a prime mission of at least five-and-a-half years, although Webb could run for a decade or more if it remains healthy and funding is maintained. The Hubble Space Telescope is famous for comet observations, and may be available in 2031 despite current problems, although predictions say it could be healthy through the mid-2020s and will be deorbited no later than the 2030s.

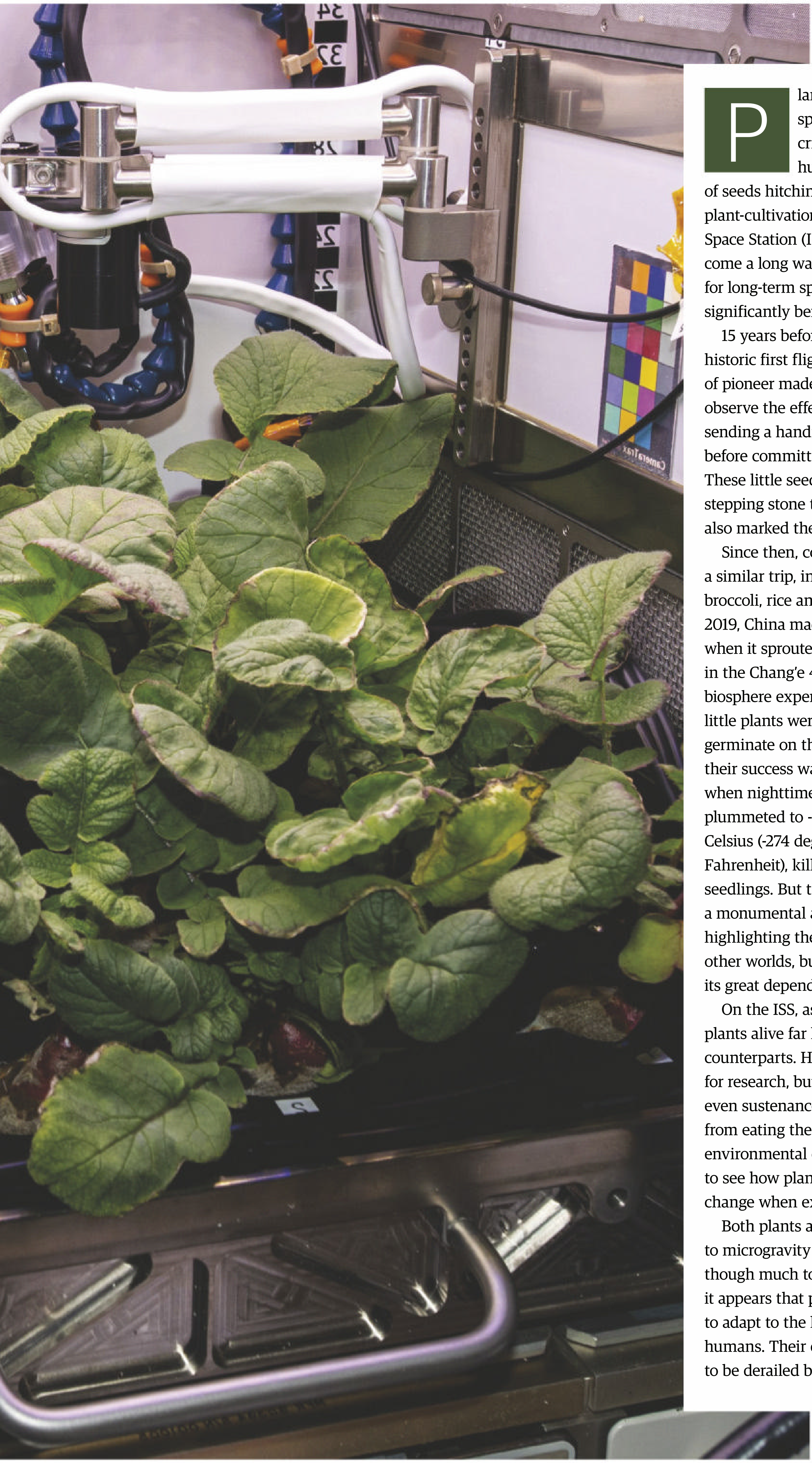
Above: The massive comet is about as far away as Uranus, making size estimates challenging

PLANTS IN SPACE

PLANTS ARE UNSUNG HEROES, ESSENTIAL FOR LONGER TERM DEEP-SPACE EXPLORATION BY CREWED SPACECRAFT

Reported by Daisy Dobrijevic

© NASA; Getty



Plants have played a pivotal role in space exploration efforts and will be critical for future space travel. From humble beginnings of just a handful of seeds hitching a ride into orbit to sophisticated plant-cultivation systems on the International Space Station (ISS), space-based plant research has come a long way. Astrobotany is not only integral for long-term space travel endeavours, it has also significantly benefited our lives here on Earth.

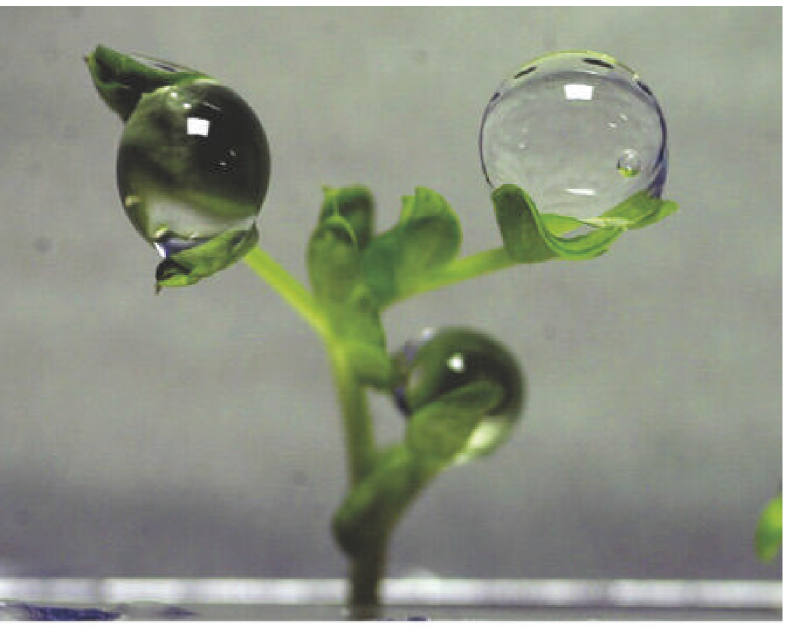
15 years before Yuri Gagarin embarked on his historic first flight into space, a very different kind of pioneer made the trip. Scientists wanted to observe the effects of space on biological material, sending a handful of maize (corn) seeds into orbit before committing to anything more substantial. These little seeds were not only an important stepping stone to getting humans into space, but also marked the dawn of the astrobotany era.

Since then, countless plant varieties have made a similar trip, including spinach, broccoli, rice and lettuce. In 2019, China made history when it sprouted cotton plants in the Chang'e 4 lunar lander biosphere experiment. These little plants were the first to germinate on the Moon, though their success was short-lived when nighttime temperatures plummeted to -170 degrees Celsius (-274 degrees Fahrenheit), killing the young seedlings. But this was still a monumental achievement, highlighting the possibility of plant growth on other worlds, but also the fragility of such life and its great dependency on technology.

> “GROWING PLANTS ON BOARD ADDS A SENSE OF NATURE, A SENSE OF HOME AND A SENSE OF LIFE TO THE ISS”
>
> MIKE HOPKINS

On the ISS, astronauts have been able to keep plants alive far longer than their lunar-based counterparts. Here plants are not only grown for research, but also ornamental purposes and even sustenance – even astronauts can't get away from eating their greens! The ISS provides unique environmental conditions to conduct experiments to see how plant growth and behaviour change when exposed to microgravity.

Both plants and humans have to adapt to microgravity during their space voyages, though much to the surprise of scientists, it appears that plants are far quicker to adapt to the lack of gravity than humans. Their development doesn't appear to be derailed by microgravity, and they still



© NASA

manage to orientate themselves correctly despite there being no clear 'up' or 'down' in space.

On Earth we know that plant roots grow down away from light and shoots grow up towards it. From these observations, scientists believed that plant development – specifically plant growth direction – was driven by both gravity and light. However, plants surprised scientists when their root growth away from light and shoot growth towards it were unaffected by the lack of gravity in space. This proved that light is the dominant driver of plant growth direction, not gravity. This revelation would not have been possible without experiments carried out in space.

Space-based research isn't just beneficial for learning more about how our little green friends behave, it has also greatly influenced our lives here on Earth. In 1989, the NASA Clean Air Study found that certain plants were particularly good at 'cleaning' the air around them. These air-filtering plants rid the air of pollutants and toxins, which could not only help sustain a healthy environment for astronauts, but also benefit those of us who spend a lot of time indoors. Chemicals such as formaldehyde, benzene and ammonia can be released in small amounts by regular household products such as printing inks, varnishes, paper towels and plastics. While adverse health effects such as nausea and headaches depend on the level of exposure to such chemicals, certain houseplants can help limit this exposure by removing these pollutants from the air. Plants such as English ivy, variegated snake plants, peace lilies and spider plants are considered some of the best for their air-cleaning qualities. These results have greatly influenced the popularity of air-filtering houseplants to this day.

While plants are natural air and water purifiers, they cannot operate at the levels required to keep space environments safe for astronaut colonisation. Instead scientists are trying to understand how plants remove such toxins from their environment to come up with new technologies that can keep space-based environments habitable. At the moment sophisticated equipment helps scrub the air of pollutants, but is not self-sufficient and requires replacement of parts during supply

Left: Water acts differently in space – here droplets form on leaves on the ISS

Right: Colonisation of other worlds such as Mars will require sophisticated food-growing technologies that can provide essential nutrients and vitamins to support deep-space exploration

> "THESE PLANTS ARE A CONNECTION TO EARTH"
>
> MIKE HOPKINS

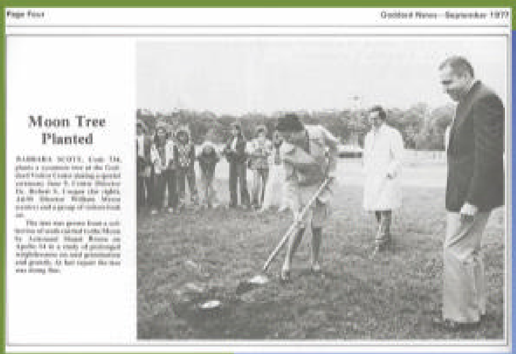
MOON TREES

These seeds flew further than most humans ever will

When Apollo 14 launched on 31 January 1971, it was carrying a little more than astronauts Alan Shepard, Edgar Mitchell and Stuart Roosa. Stowed away in Roosa's personal kit were hundreds of tree seeds that orbited the Moon in the Command Module along with Roosa while Shepard and Mitchell walked upon the lunar service. Five different species of tree seeds were taken into orbit: loblolly pine, sycamore, sweetgum, redwood and Douglas fir. The seeds were part of a NASA and US Forest Service (USFS) joint project, and upon their return to Earth were germinated by the USFS.

The resulting 'Moon trees' were then planted throughout the US and in other parts of the world as a living tribute to the Apollo program, and were part of the bicentennial celebrations in 1976. A loblolly pine was planted at the White House, and other trees were said to be planted in Brazil, Switzerland and even presented to the emperor of Japan. However, due to poor record-keeping, the exact locations of all the Moon trees is a mystery. NASA astronomer David Williams has taken it upon himself to search for them. When he began his endeavour in 1996, only 22 Moon tree locations were known, but now that number has climbed to over 90. Sadly, a number of the original Moon trees are no longer alive, including the White House loblolly pine, but there may be plenty more healthy Moon trees around the world simply waiting to be discovered.

Some Moon trees were grown next to their 'control' counterparts – which had not made the trip to space – so any differences in growth caused by exposure to microgravity could be assessed. No such differences were found, and many Moon trees of the world still flourish today, including the sycamore tree at NASA's Goddard Visitor Center that was planted on 9 June 1977. Some of these Moon trees have even produced offspring, which are commonly referred to as half-Moon trees. One such half-Moon tree stands tall at NASA's Marshall Space Flight Center.



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Goddard News – September 1977

Moon Tree Planted

Above: Barbara Scott plants a sycamore Moon tree at Goddard Visitor Center on 9 June 1977

Right: A sycamore Moon tree at Mississippi State University

x2 © NASA

© NASA

DID YOU KNOW?

The first vegetable to be grown in space was the potato. In 1995, small potatoes were grown aboard Space Shuttle Columbia in its microgravity astroculture laboratory.

TAP HERE TO PLAY

missions. While this is fine for current research missions, it will become harder to resupply those that venture further from Earth and for longer periods of time.

For longer term missions, sophisticated bioregenerative support systems are needed. These will support life by providing oxygen and removing carbon dioxide from the air, purifying water and providing food. Such systems require a good relationship between plants and technology, as plants can help make the environment habitable through air and water purification and food supply, but they need the right technology, such as light supply, to enable them to grow. These closed-system ecosystems are being tested in Earth-based research facilities such as Biosphere 2 in Arizona and BIOS-3 in Russia to assess how such systems could maintain and support life in space.

Another benefit of growing plants in space is a rather simple one: sustenance. According to NASA, stored food represents the largest consumable mass - apart from rocket fuel - for human spaceflight. To sustain long-duration exploration missions, astronauts need to be able to grow more of their food, as raising livestock in space would be impractical and a logistical nightmare.

On the ISS there are a variety of plant-growth experiments designed to study in-orbit plant growth and performance. In 2015, Expedition 44 crew members enjoyed the fruits of their labour when they harvested their 'Outredgeous' red romaine lettuce, and were permitted to eat half of their bounty. The other half was packaged up to return to Earth for further experimentation. This marked the first-ever crop to be grown and eaten in space, a giant step forward in space-based food-production research.

This important research not only aids future space exploration efforts, but also has implications for our future here on Earth. "If we can discover how to sustainably grow healthy, robust and consistent crop yields in a place as inhospitable to life as Mars, we can apply these discoveries to transform how we grow food here on Earth," says Gil Cauthorn, a PhD student at the University

© NASA

Above: NASA astronaut Peggy Whitson with a fruitful harvest of cabbage plants from the Veggie growth system on the International Space Station

TIMELINE

Many plants have spread their roots in space

9 JULY 1946

Maize seeds became the first seeds to travel to space when they were launched aboard a V-2 rocket.

31 JANUARY 1971

NASA's Apollo 14 mission was launched, taking seeds into orbit around the Moon. Upon their return to Earth, the seeds were distributed to grow 'Moon trees'.

1982

Arabidopsis thaliana became the first plant to flower and produce seeds in space when it was grown on board the Soviet Union's Salyut 7 spacecraft.

15 SEPTEMBER 1989

The Clean Air Study was published by NASA.

10 JUNE 1990

The plant habitat SVET arrived at the Mir space station.

7 MAY 2014

The Veggie growth system was installed in the ISS Columbus module by astronauts Steve Swanson and Rick Mastracchio.

10 AUGUST 2015

The ISS Expedition 44 crew became the first US astronauts to eat plants that had been grown in space when they tucked into their red romaine lettuce.

16 JANUARY 2016

Zinnia flowers grown on the ISS opened their petals for the first time - much to the delight of astronaut Scott Kelly, who took a particular interest in ensuring the plants grew successfully.

15 JANUARY 2019

The first plants were grown on the Moon on board the Chang'e 4 lunar rover. Cotton plants sprouted, but did not survive through the lunar night due to freezing temperatures.

HOW DOES A SPACE GARDEN GROW?

Explore the different experiments growing life on the ISS

There's a variety of plant-growth experiments currently being conducted on the ISS. These studies are mainly designed to investigate how microgravity affects plant growth and development in order to assess the logistics of plant production during long-term space missions. There are also a couple of side benefits. In return for their hard work, astronauts receive a refreshing boost to their freeze-dried diet and experience the simple pleasures of gardening, which enhances their general happiness and wellbeing.

The Vegetable Production System (Veggie) is perhaps the most well-known growth unit on the ISS. The space garden has featured in many photographs taken on the ISS, showing astronauts proudly presenting the fruits of their labour. "I have been intrigued by the Veggie experiments on the International Space Station and wanted to be a part of learning how to grow plants in space," says NASA astronaut Mike Hopkins.

The Veggie system is the most 'hands-on' plant-growth system on the ISS, and is about the same size as a piece of carry-on luggage. There are currently two Veggie units on the ISS, each capable of growing about six plants. A variety of fresh produce has already been grown using the Veggie system, including lettuce, Chinese cabbage, mizuna mustard, red Russian kale and the infamous zinnia flowers that astronaut Scott Kelly took a shine to. Kelly documented his efforts nursing dying zinnias back to health on the ISS, regularly tweeting plant health updates. To his delight he saved the plants, which subsequently erupted in blooms of vibrant orange.

The Veggie growth system is a relatively simple concept. As we all know, soil is messy at the best of times, let alone in microgravity conditions. So in Veggie, plants are anchored into 'pillows' filled with clay-based growth media and fertiliser. Water is precisely injected into the growth pillows. These special pillows also help to ensure the plant roots have access to a healthy balance of air, water and nutrients. Without this set-up, the roots would find themselves either drowning in water or completely engulfed by air, as fluids in space tend to form bubbles. The first crop grown in the Veggie system was red romaine lettuce, planted by astronaut Steve Swanson. It grew for 33 days before being harvested, with some returned to Earth for food-safety tests. The results showed the lettuce was safe to eat, and even suggested it to be cleaner than fresh produce purchased from a supermarket.

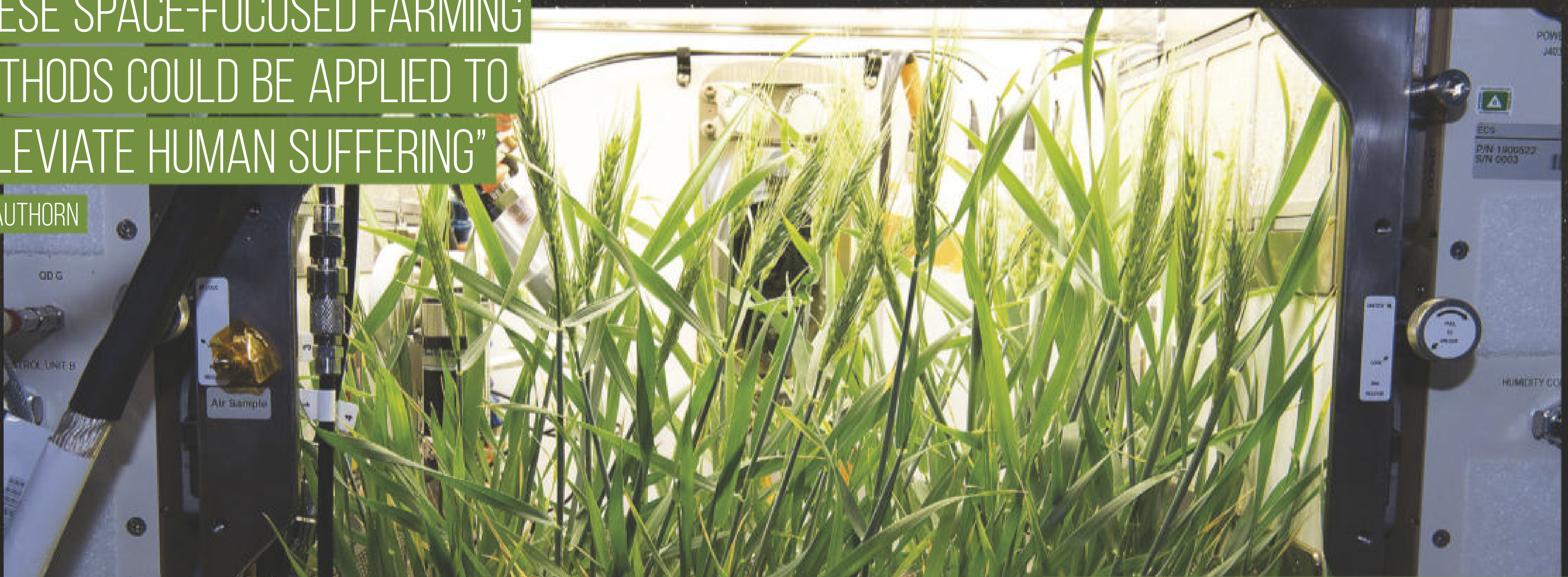
Below: A dwarf wheat variety was one of the first test crops grown in the Advanced Plant Habitat aboard the International Space Station

Below inset: Before their launch to the ISS, seeds are planted into special plant pillows for the Veggie system

Another growth system on the ISS is the Advanced Plant Habitat (APH). It is similar to Veggie in that it uses light-emitting diodes (LEDs) and clay-based growth media for controlled growth, but unlike Veggie, this system is purely automated. The APH is controlled by a ground team at the Kennedy Space Center, who keep an eye on the plants with cameras and more than 180 sensors. With watering, temperature, light and atmospheric humidity levels all controlled by ground teams, the APH doesn't require much day-to-day maintenance from the astronauts. The sophisticated APH light system contains a wider variety of LED lights than Veggie, with red, green and blue lights as well as white, far red and infrared to support nighttime imaging. The first experiment carried out in the APH grew *Arabidopsis thaliana* for about six weeks and dwarf wheat for five weeks in 2018.

On a much smaller scale to Veggie and APH are the Biological Research in Canisters (BRIC). These experiments are carried out in small petri dishes and are designed to look at the effects of space on much smaller organisms such as microbes, mosses and algae. With these experiments, scientists want to investigate whether the space environment negatively affects plant defences. After Kelly nursed several zinnia plants back to health after a fungal infection killed off the rest, it was suggested that plants in space may struggle to fend off pathogens for themselves. This could be disastrous for long-term space missions that are relying on plant production for food. The latest BRIC-LED experiment – BRIC-LED-002 – was delivered to the ISS on SpaceX's 20th commercial resupply mission in March 2020.

> "THESE SPACE-FOCUSED FARMING METHODS COULD BE APPLIED TO ALLEVIATE HUMAN SUFFERING"
>
> GIL CAUTHORN



TAP HERE TO PLAY

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Above: Orange zinnias were one type of flower successfully grown in space

Right: NASA astronaut Mike Hopkins with 'extra dwarf' pak choi plants growing aboard the ISS

of North Dakota and Astrobotany International Research Initiative (AIRI) program director. "These space-focused farming methods could be applied to alleviate human suffering associated with food production while also transitioning towards a more environmentally sustainable agricultural infrastructure".

Plants don't just have the ability to keep astronauts well fed, they will be critical in keeping astronauts healthy during long-term missions. Currently, astronauts take multivitamins and enjoy a rich selection of prepackaged meals carefully prepared to cover their dietary needs. However, over time, vitamins in prepackaged form break down. While this is not a serious issue for current space expeditions, which experience regular resupply missions, it will be a problem for future long-duration space travel. Vitamin deficiencies can cause serious health problems – after all, a lack of vitamin C was all it took to plague sailors with scurvy. Luckily for our space-faring travellers, we now understand the value of vitamins, and although prepackaged vitamins are unsuited for future long-term space exploration, fresh produce offers nutrients and vitamins in a long-lasting, easily absorbable form.

Plants are not only important for keeping astronauts in tip-top physical condition, they are also advantageous for their mental health. It turns out that growing a little piece of Earth so far from home can help make living in space feel a little less alien. According to NASA, many astronauts found caring for plants in space a fun and relaxing activity, and many would volunteer their spare time to help with gardening duties.

"These plants are a connection to Earth. The look, feel, taste and smell all remind us of life on Earth, and that connection is good for our mental health," NASA astronaut Mike Hopkins tells **All About Space**. "The space station is a world-class laboratory, but can feel a bit sterile at times. Growing plants on board adds a sense of nature, a sense of home and a sense of life to the space station."

Plants are therefore critical components of future long-term space travel and the potential colonisation of other worlds. While companies invest a great deal of time and money into building the latest and greatest rocket technology, without effective plant-growth strategies, crewed deep-space exploration missions are impossible. Plants are oxygen makers, water purifiers, air cleaners and food givers. While modern rocket technology may get us into space, it's plants that will keep us there.

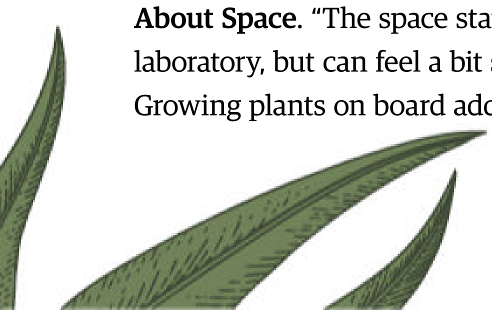
DID YOU KNOW?

The colour of light affects plant growth. While blue light is crucial to germination and early plant development, red light is important for photosynthesis. Blue light combined with red light can help encourage the flowering of plants. Plants make good use of visible light, converting it to glucose via photosynthesis. Advanced LED technology allows for even tighter control of the light exposed to plants at different stages of their life cycle.

Daisy Dobrijevic
Staff Writer
Daisy is **All About Space**'s Staff Writer. She previously worked for *BBC Factual* as a researcher and *BBC Sky at Night* magazine as an editorial assistant.

© NASA

Right: The crew on board the ISS check to see if the plants in the VEG-04 experiment need any water



RETHINKING BLACK HOLES

Delving deep into the workings of these high-gravity objects could turn our theories on their head

Reported by Leo Bear-McGuinness

© Tobias Roetsch

Almost every diagram of a black hole highlights two key parts of these behemoth beasts: the singularity (the centre) and event horizon (the perimeter). But there's a chance some black holes don't actually look like this. Some black holes may not have an event horizon at all. If they exist, these naked singularities wouldn't just call every black hole illustration into question, but many of our established notions of the universe, too.

A standard black hole is thought to be the consequence of a large star collapsing in on itself. Once compressed into a point of infinite density, the forces of gravity are so extreme that nothing can escape its pull, not even light. But for something to get in, it still has to get close enough, past the event horizon. "The simplest way to describe them is as a point of no return," says Maximiliano Isi, a postdoctoral researcher at the Laser Interferometer Gravitational-Wave Observatory (LIGO) Lab at the Massachusetts Institute of Technology (MIT). "It's sort of like the frontier between countries. It's not a geographical thing. If you try to get out, once you've gone past that point, you will find that you won't be able to."

If you were unfortunate enough to be caught in this fatalistic force, you would be pulled right into the heart of the black hole with no means of escape. This engulfing process would even occur at different rates for different parts of your body. Limbs closest to the black hole would be yanked the hardest, stretching and tearing your body in a process known as spaghettification.

After this gruesome event, your spaghettified body would be sucked into the singularity. It's here where your remains would be compressed down into an infinitely tiny point, along with any other matter that had befallen the black hole. But here's where things get confusing. Up until now, every part of the process of falling into a black hole, including the black hole itself, can be explained by Einstein's theory of general relativity. But within this singularity, it's thought that the curvature of space-time itself would split from equations, rendering this universal theory somewhat less universal. It's partly why Einstein and many of his contemporaries doubted that such a physical black hole was possible. Einstein's collaborator in proving general relativity, Arthur Eddington, even went as far as insisting "there should be a law of nature to prevent a star from behaving in this absurd way". For decades, an open belief in black holes would get you laughed out of a physics lecture hall.

Attitudes changed as time went on, in large part because of the calculations and theories of two men: Stephen Hawking and Roger Penrose. While Hawking may be the more well known of the two, it was Penrose who first salvaged black holes from the rubbish heap of physics. Realising in 1969 that Einstein's theory and black holes could happily coexist if singularities were somehow hidden from the rest of space-time, Penrose postulated the existence of event horizons, great cloaks that would surround black holes, hide them from view and act as a perimeter for their gravitational effects.

"Einstein was trying to get rid of singularities in black holes, because

"IF YOU TRY TO GET OUT, ONCE YOU'VE GONE PAST THAT POINT, YOU WON'T BE ABLE TO"

MAXIMILIANO ISI

TAP HERE TO PLAY

© Getty

Left: Stephen Hawking studied many aspects of black holes, including how they 'leak' out into space

1,500

THE APPROXIMATE NUMBER OF LIGHT YEARS BETWEEN EARTH AND ITS NEAREST BLACK HOLE

1964

THE YEAR THAT A BLACK HOLE WAS FIRST DETECTED, USING COSMIC X-RAYS

he thought it was just a horrible thing," says Tomas Andrade, a postdoctoral theoretical physicist at the University of Barcelona. "Penrose and Hawking realised that these singularities are there. If general relativity is correct, singularities are going to happen. Penrose realised that you don't come across singularities very often, and he conjectured that's the case because the universe protects the singularities by covering them with a black hole horizon."

Penrose called his idea the weak cosmic censorship conjecture. From then on, physicists largely acted like event horizons were a compulsory part of black holes - the mandatory packaging that came with a singularity. But are they? After all, even with inclusion of event horizons, the theory of general relativity still seems to crumble apart when it reaches the singularity. It's partly why physicists are trying to set out a more complete theory of quantum gravity, which could account for such inconsistencies. And if a new theory is ever devised, there's a chance it could happily incorporate the naked singularities Penrose's conjecture prevents. But the theoretical physicists working on this quantum theory had better get a move on, because the evidence for naked singularities is already piling up.

"A huge amount of these counter examples come from looking at higher dimensional gravity," says Andrade. "If you look at general relativity, not in four dimensions, like us - we live in three space dimensions plus time - if you increase the number of space-time dimensions, you can form the [naked] singularities in a much more natural way."

A universe with more than four dimensions might sound a little science fiction, even for physics, but the concept is a crucial part of string theory, another rival for general relativity's top spot in the league of theories to describe the universe. As the theory goes, all matter and forces in the universe are actually tiny vibrating strings that twist and turn in all kinds of directions, including into other dimensions. And within such 5D, 6D or 7D universes, the rules for black holes may be very different to how we currently understand them - different enough that naked singularities could freely exist. This is what Andrade and his colleagues at the University of Barcelona tried to determine in a recent computer simulation.

"[We have] a toy model that allows you to look at collisions of black holes in a higher number of dimensions," he says. "This means you can simplify Einstein's equations, and something that can take months to do in a supercomputer, you can simulate a simplified version of this in less than a minute on your laptop. It's quite cool."

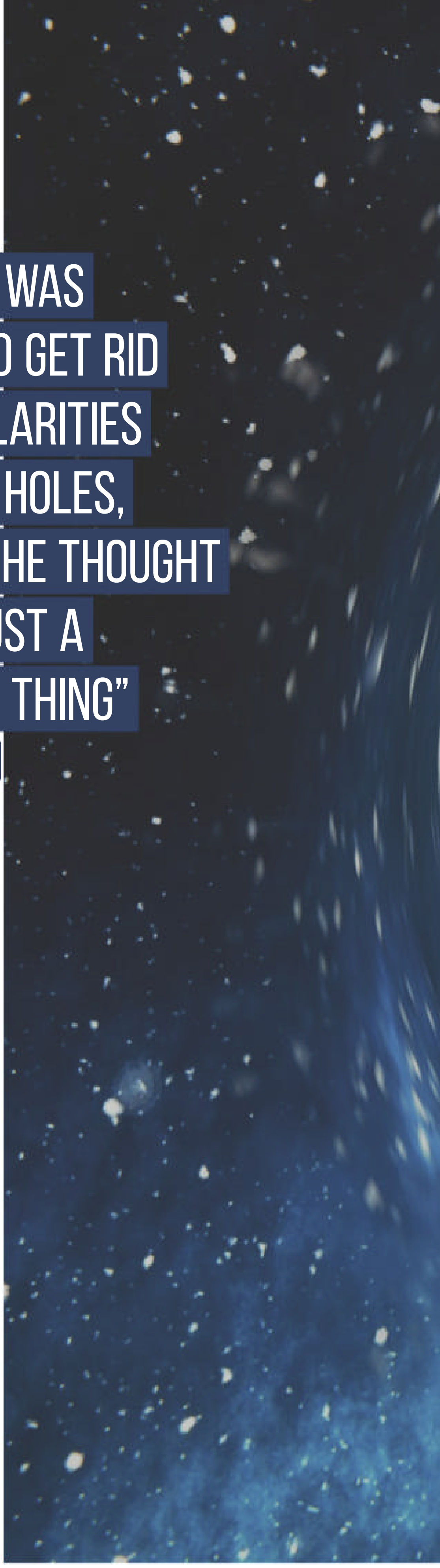
After running the simulation, Andrade and his colleagues found that if two rotating black holes were to collide and form a new black hole in a 7D universe, the force would be enough to elongate the new black hole's event horizon, eventually making it untenable. "We saw that you can form a tube of horizon that then breaks," he explains. "And when you get really close to the breaking point is when you form a naked singularity. Then the description of general relativity ceases to be valid."

While Andrade's study is a significant step towards describing and understanding naked singularities, it's only part of the puzzle. After all, we can't say for certain the universe really does have six or seven dimensions. To study horizonless black holes in the standard four dimensions, we might just have to find them.

"Our role in LIGO is to try to bring some more observational information to this discussion," Isi tells **All About Space**. From his position at LIGO, Isi and his colleagues have been able to analyse and test the most potent proof of black holes there is: gravitational waves. Back in 2015 the observatory provided the first tangible evidence that these kinds of waves existed when it detected the gravitational waves of two colliding black holes. More recently, Isi used the data to confirm a concept Stephen Hawking described in 1971 - the Hawking area theorem.

According to the eminent physicist, the event horizon area of the new black hole shouldn't be any smaller than the total horizon area of its parent black holes. Indeed, 50 years after the theorem was made and six years after the gravitational

> "EINSTEIN WAS TRYING TO GET RID OF SINGULARITIES IN BLACK HOLES, BECAUSE HE THOUGHT IT WAS JUST A HORRIBLE THING"
>
> TOMAS ANDRADE



Below: Black holes aren't the only cause of these ripples. Neutron stars can also be at the source

Right: Gravitational-wave detectors stretch across great distances to pick up tiny vibrations in space-time

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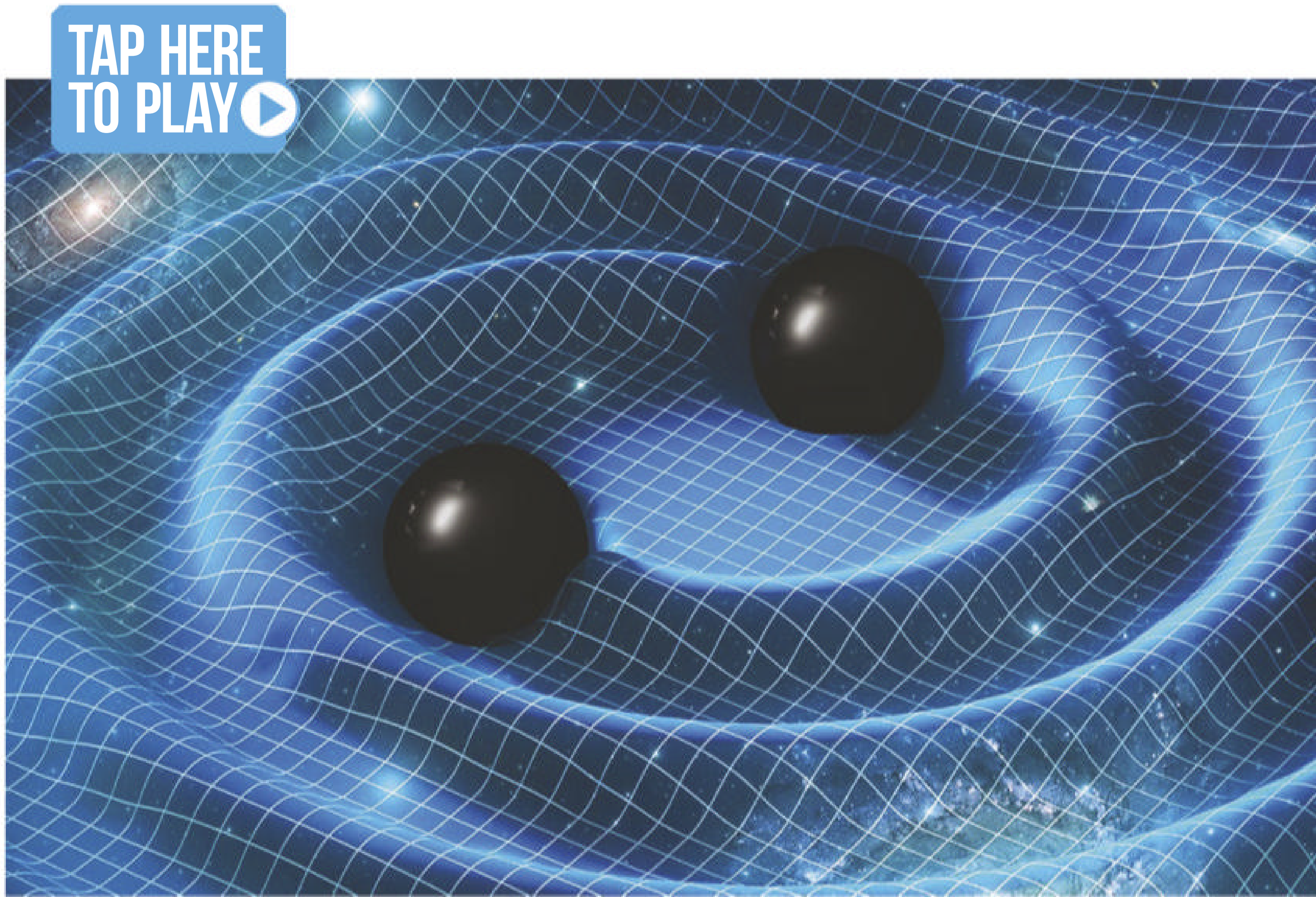

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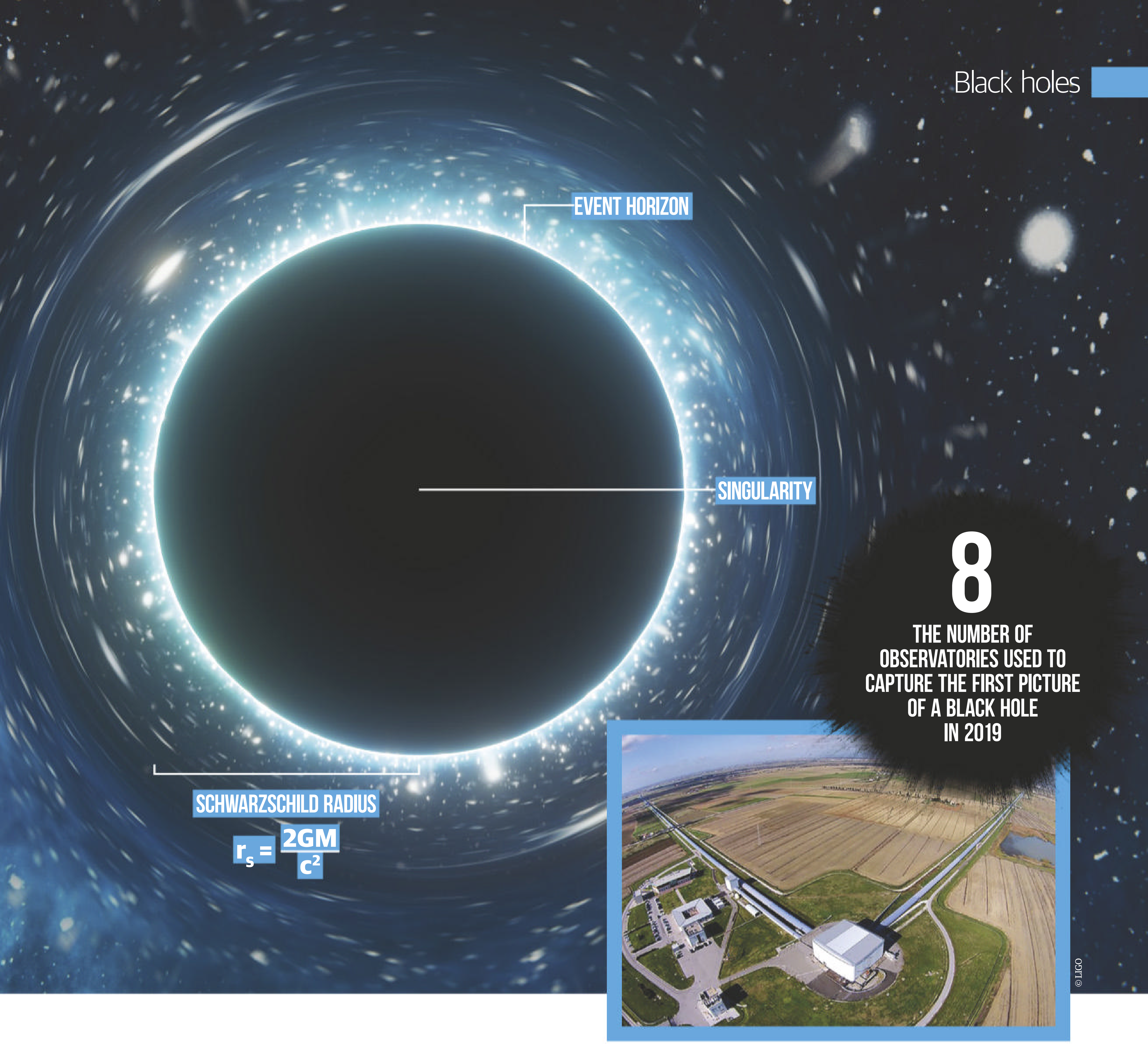

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8

THE NUMBER OF OBSERVATORIES USED TO CAPTURE THE FIRST PICTURE OF A BLACK HOLE IN 2019

waves were first detected, Isi and his team proved Hawking right when they found that the new black hole's event horizon was no smaller than the total area of its parents' horizons. "So far everything we've thrown at the data has come back and told us it's in agreement with the expectation from the vanilla picture that we have from Einstein's theory, which includes these theorems about the area from Hawking," he says.

But as impressive as LIGO is, Isi says its accuracy is a bit duller than ideal. To really test gravitational waves and the black holes that generate them, the team at MIT are going to need to upgrade their kit. Work is already underway to improve the sensitivity of LIGO and Virgo, a laser observatory in Italy, but the real advance will come with the Laser Interferometer Space Antenna (LISA), a network of three gravitational-wave detectors that will span vast distances in space. With a colossal range and the quiet stillness of space, it's hoped the NASA and European Space Agency project, due to launch in 2034, will be able to detect the movements of black holes to an unprecedented degree. "Those instruments will see every single black hole collision in the universe… every single one," Isi says. "They're so sensitive that they can reach to the point where there are no longer any black holes, so far away that they haven't had time to form."

As soon as LISA launches to its spot among the stars, there'll be no place for black holes to hide. When this day comes, maybe physicists like Isi will detect a singularity that seems bereft of its event horizon. And that's when things will get really interesting. "Maybe some portion of the objects that we see [will be] more like the objects we expect from Einstein's theory, with the look more like a normal black hole with a normal horizon," Isi says. "And maybe there's some fraction of them that are more exotic, that were formed by a different process and have different properties. Finding these rare objects will require analysing a very large number of signals, which will be facilitated by the improving instruments."

Leo Bear-McGuinness
Science writer
Leo holds a master's degree in science communication and public engagement. He has written for a variety of magazines and websites.

PLANET PROFILE
JUPITER

The largest planet has a lot to tell us

Reported by Ian Evenden

Fifth in the eight-planet line-up of our Solar System, Jupiter also happens to be the largest, and by quite some distance. The mass of this gigantic ball of gas is two-and-a-half times that of all the other planets put together, and you could fit 11.2 Earths within its radius. While there's likely a rocky core somewhere under the enormous gaseous atmosphere, scientists can't be sure whether it's solid or not, but gravitational measurements suggest it could make up as much as 15 per cent of Jupiter's mass.

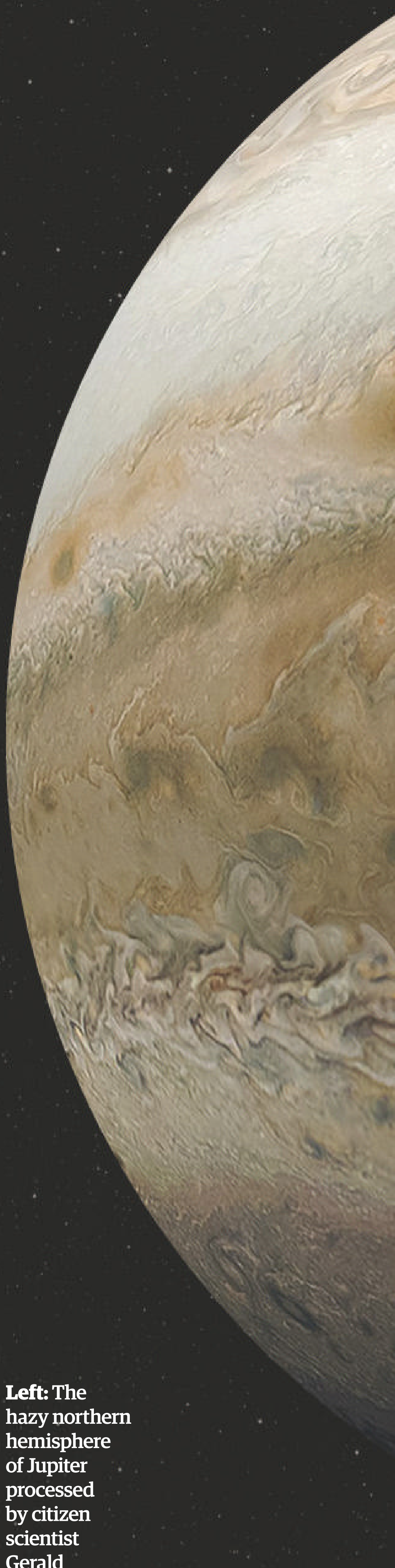
What is known is that Jupiter is contracting, and this generates more heat than the planet receives from the Sun, warming the huge number of moons that orbit around it. It also has a faint ring system, too thin to be seen from Earth with any but the largest telescopes and first spotted by the Voyager 1 probe in 1979.

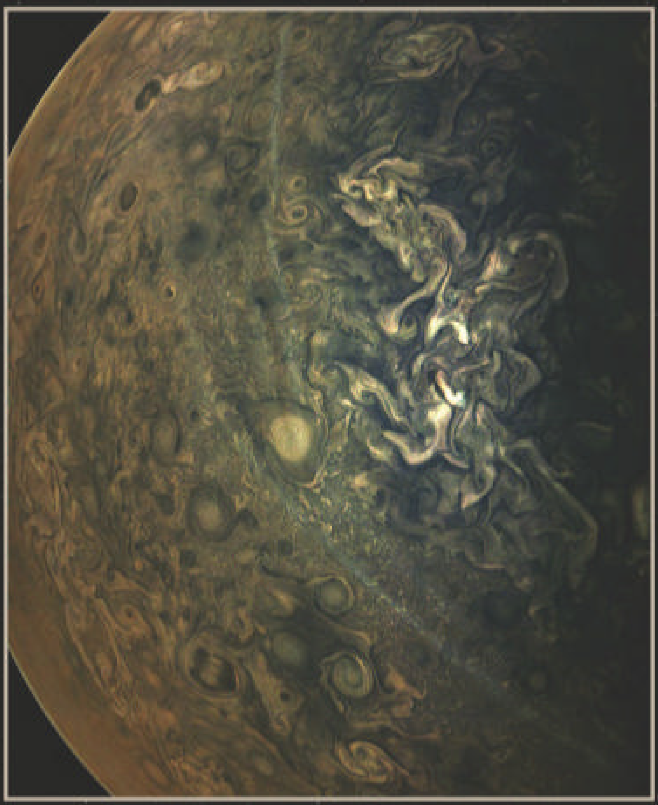
Jupiter plays a major role in many theories of the formation of our Solar System. In one, known as the grand tack hypothesis, Jupiter formed at 3.5 AU - 1 AU is the Earth-Sun distance - before plunging inward towards the Sun until it reached 1.5 AU, then reversing course and moving out again, stopping at its current distance of 5.2 AU. It crossed the asteroid belt twice, scattering rocks in all directions and contributing to the low mass of the belt today. It may also have caused rocky planets orbiting closer to the Sun to crash into the star's surface. This answers questions such as why Mars is so small - Jupiter's presence limited the material available for its formation - and why there are no large planets orbiting close to the Sun, as we see in other solar systems.

Jupiter has also had a long-lasting effect on the rest of the Solar System. It has a fleet of asteroids and comets that follow it through its orbit - over 2,000 have been discovered - and its great mass means that the centre of gravity for it and the Sun lies above the Sun's surface, meaning they act almost like a binary system. The giant planet's gravity well also means it can intercept comets and asteroids heading into the inner Solar System, and may partially shield the inner planets from bombardment. Another theory, however, is that it actively draws small bodies in from the Kuiper Belt. Whichever is true, Jupiter experiences 200 times more impacts than Earth.

Visible with the naked eye from Earth, Jupiter represented the god Marduk to the Babylonians, and it was Phaethon to the ancient Greeks. The Romans assigned it to their king of the gods, whose name it bears today, whereas to Hindu astronomers it was Brihaspati, or Guru, which means 'heavy one'. Across Asia it was known as the Wood Star, a name taken from the Chinese theory of the five elements.

Galileo discovered Jupiter's four largest moons, known as the Galilean moons, in 1610, the first time moons had been observed around another planet. Humanity has since explored the planet with observatories and space probes, beginning in 1973 with a flyby by Pioneer 10. Many missions to the outer Solar System have used Jupiter's gravity as a slingshot to correct their course or gain speed, but the first craft to orbit the planet was the aptly named Galileo in 1995.





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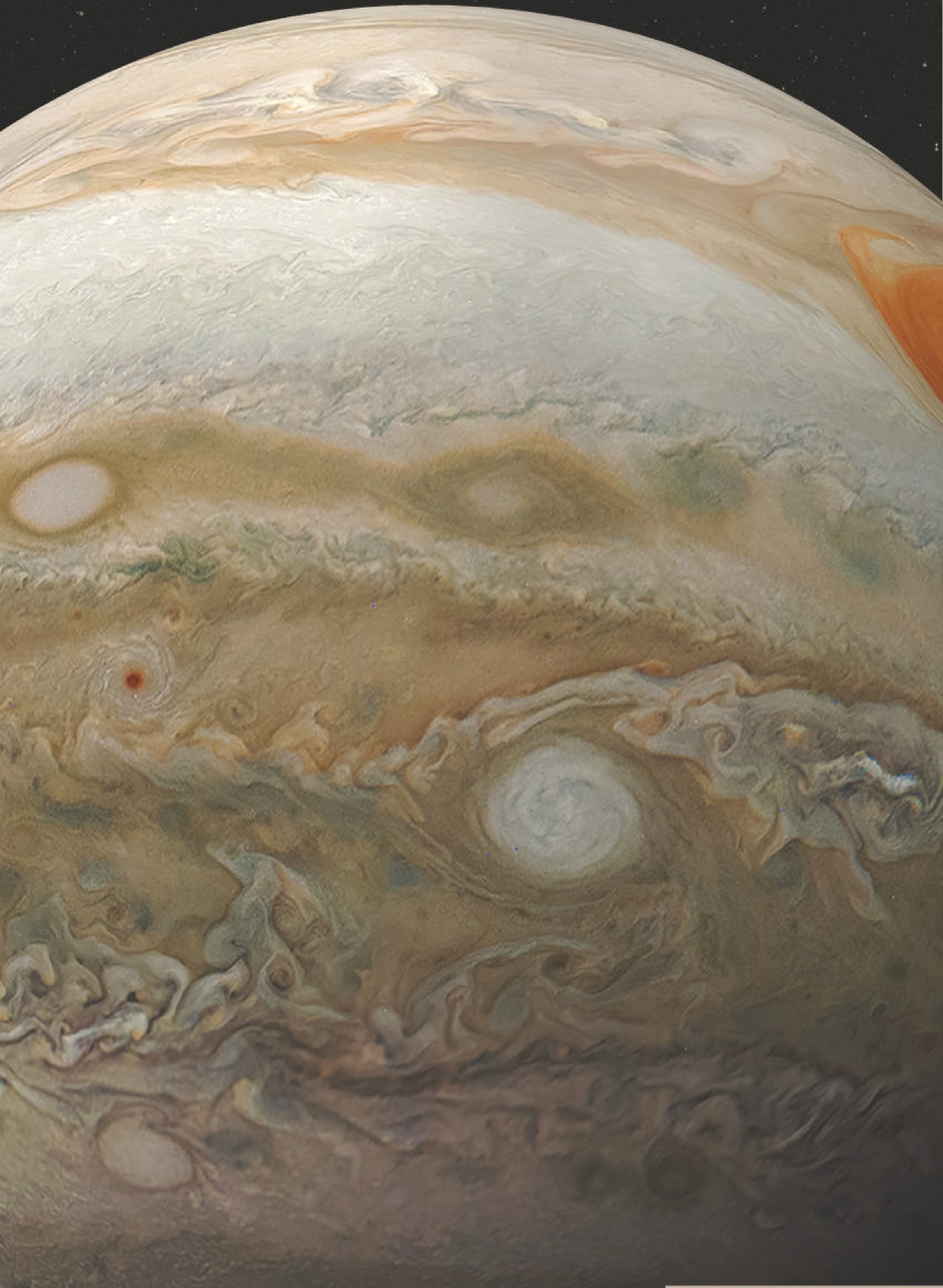
Left: The hazy northern hemisphere of Jupiter processed by citizen scientist Gerald Eichstädt from Juno camera data in 2020



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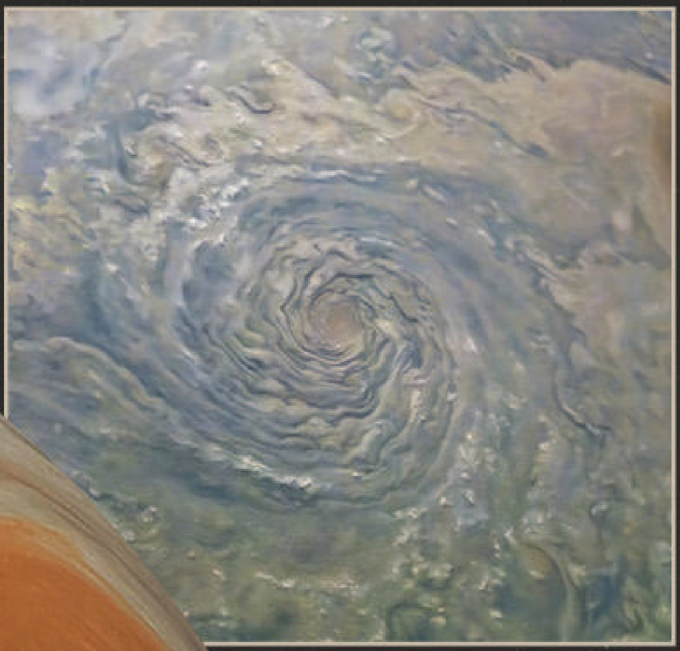

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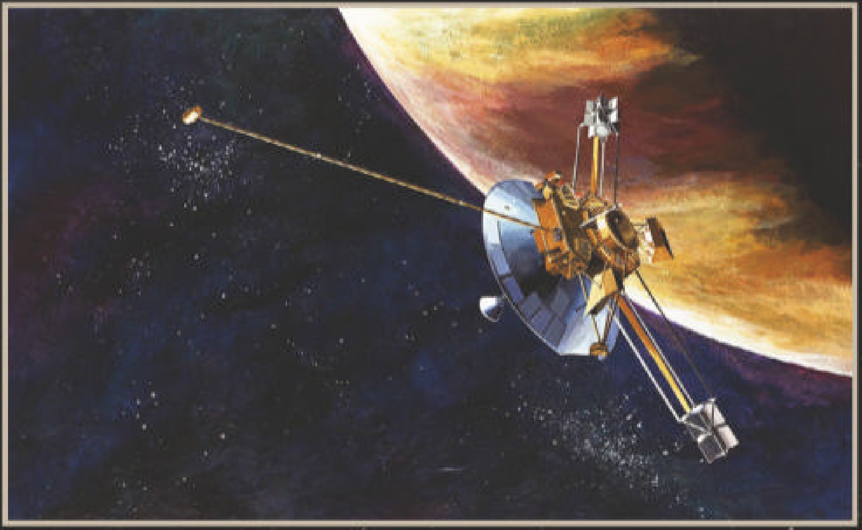
Above: A cyclonic storm in Jupiter's northern hemisphere, captured by Juno in 2019

Below: Pioneer 10 was the first human-made probe to cross the asteroid belt and fly past Jupiter

ATMOSPHERIC COMPOSITION

UPPER ATMOSPHERE	
90%	HYDROGEN
10%	HELIUM



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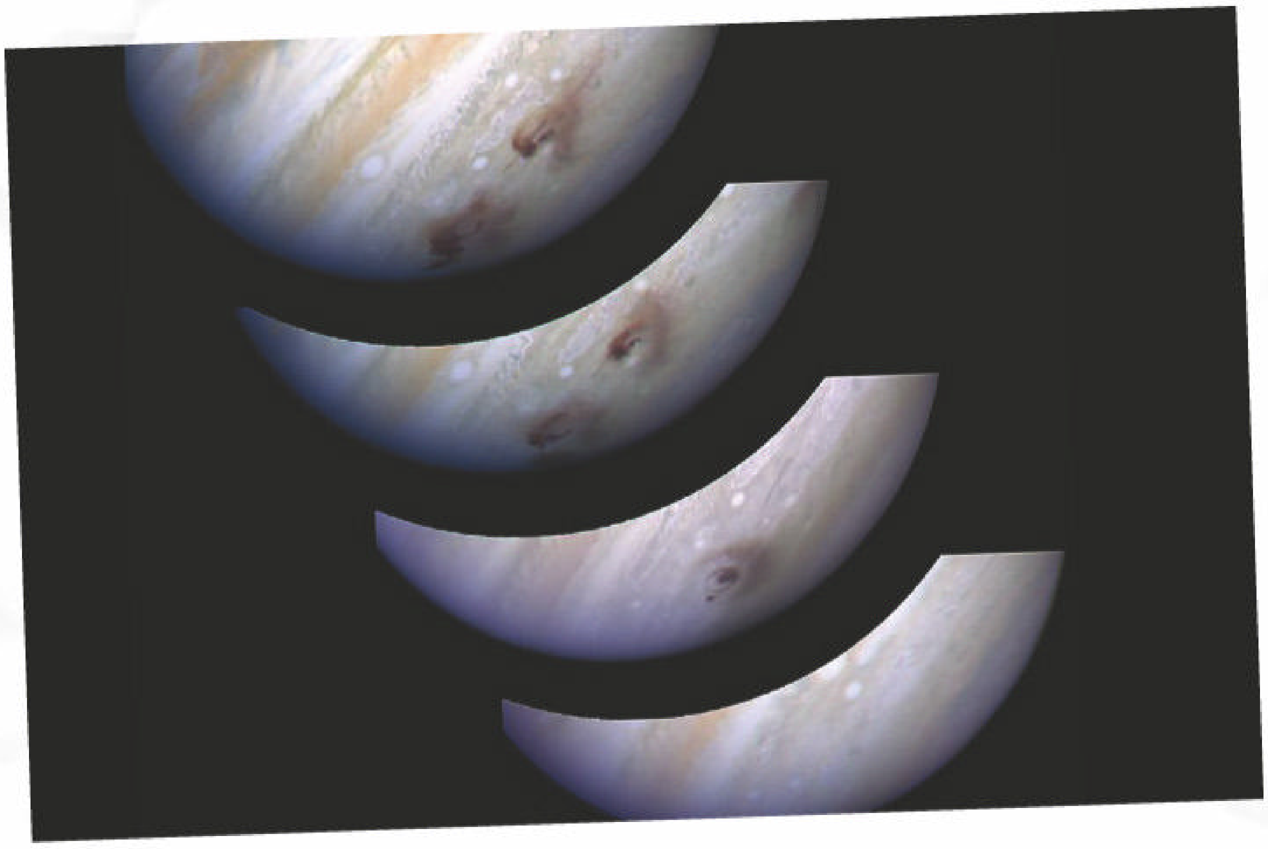
INTERIOR	
71%	HYDROGEN
24%	HELIUM
5%	OTHER ELEMENTS

NEWS FROM JUPITER

Wind speeds measured

For the first time, scientists have been able to directly measure the winds in the middle of Jupiter's atmosphere. Using the Atacama Large Millimeter/submillimeter Array (ALMA), a team of astronomers was able to track the movement of molecules of hydrogen cyanide in the planet's famously turbulent atmosphere, measuring narrow bands of wind at up to 1,448 kilometres (900 miles) per hour. The hydrogen cyanide is not native to Jupiter, but was added to the storms when comet Shoemaker-Levy 9 collided with the giant planet in 1994. Since then it has been circling the atmosphere.

"The most spectacular result is the presence of strong jets, with speeds of up to 400 metres [1,312 feet] per second, which are located under the aurorae near the poles," said Thibault Cavalié of the Laboratoire d'Astrophysique de Bordeaux in France, who led the team behind the discovery. Using 42 of ALMA's 66 high-precision antennae, the team measured the Doppler shift, tiny changes in the radiation emitted by the molecules, from which they were able to deduce wind speed.



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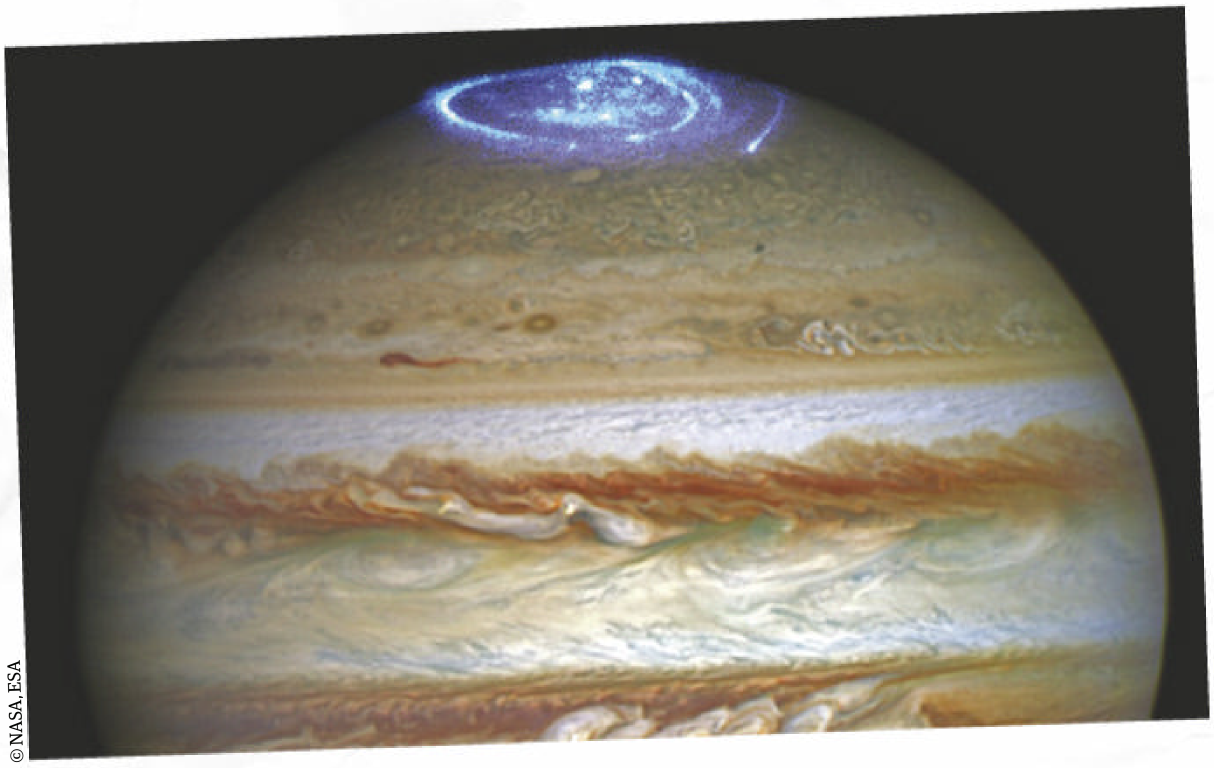

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Auroral activity

Jupiter's version of the northern lights has puzzled scientists, because it doesn't behave like the aurorae on Earth. Here the lights appear in a ring between 60 and 70 degrees north or south of the equator. Within that ring, an area known as the 'polar cap', the lights don't appear. On Jupiter, however, there is no 'polar cap' – the aurora continues its display all the way to the pole.

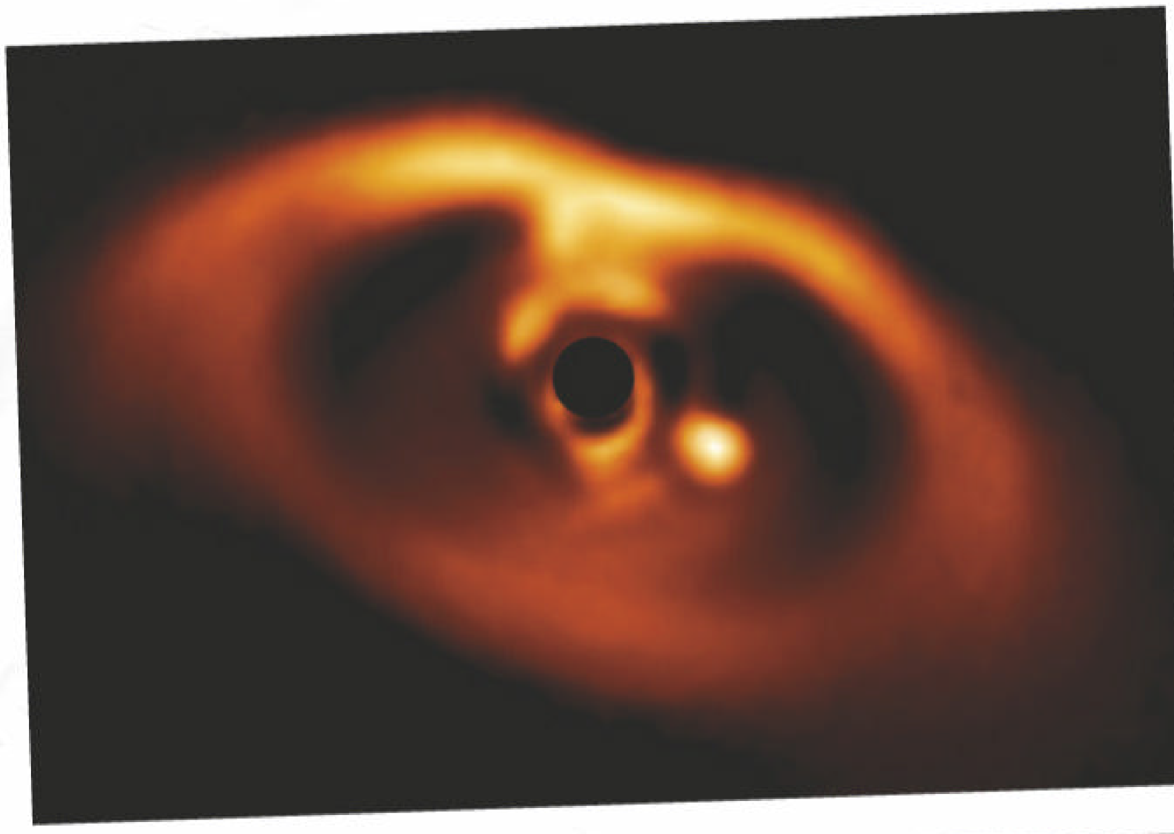
This turns out to be due to a strange quirk of Jupiter's magnetic field. On Earth, the aurorae appear on closed field lines, which extend outwards from the planet before bending back again. Inside the 'polar cap' the field lines are open – they extend out into space – and there are no aurorae. Jupiter, meanwhile, has a mixture of open and closed field lines as you approach its poles, meaning the aurorae are still able to appear.

"We as a community tend to polarise, and couldn't imagine a solution where it was a little of both," said Peter Delamere, professor of space physics at the University of Alaska Fairbanks' Geophysical Institute.

Another Jupiter

Little is known about how planets as large as Jupiter form, but a planet circling another star, and under the watchful eye of the Hubble Space Telescope, could give us a lot of information. Known as PDS 70b, the planet orbits a very young orange dwarf 370 light years away in the southern constellation of Centaurus, which has two actively forming planets within its protoplanetary disc. PDS 70b, which orbits the star at the same distance as Uranus orbits our Sun, is already around five times the mass of Jupiter, and possibly twice as large, and at a mere 5 million years old should continue to form for a little while yet, though the rate at which it is accreting more material has dwindled.

"This system is so exciting because we can witness the formation of a planet," said Yifan Zhou of the University of Texas at Austin. "This is the youngest bona fide planet Hubble has ever directly imaged; observations allowed us to estimate how fast the planet is gaining mass." Magnetic field lines turn out to play a role in the formation of such a planet, extending from the disc of dust and gas that surrounds the young star and funnelling material onto the planet's surface.



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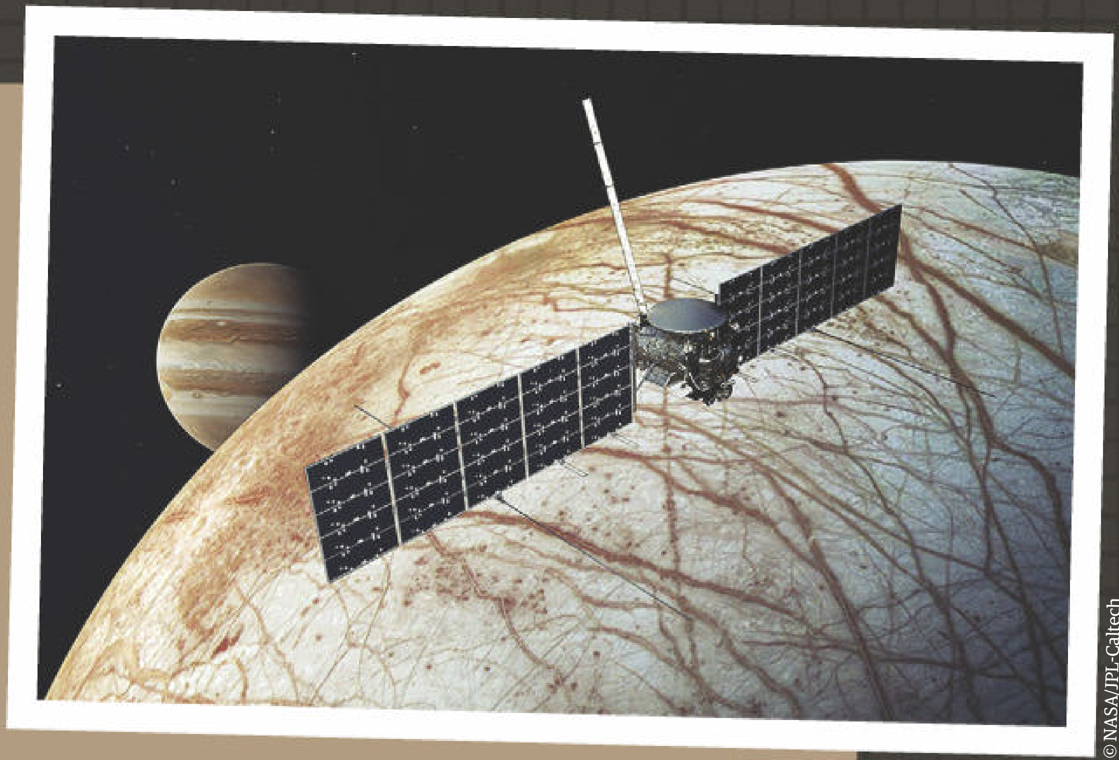
FUTURE PLANS FOR JUPITER

While Jupiter has been heavily photographed by missions such as Juno, which arrived at the planet in 2016, much scientific interest has now transferred to the planet's moons, which are thought to harbour subsurface liquid oceans and possibly even life. Europa, Ganymede and Callisto, three of the Galilean moons, would be the targets, but multiple missions have been cancelled due to lack of budget.

In 2024 NASA's Europa Clipper should launch, following up on studies from the Galileo probe and performing multiple flybys of Europa without orbiting it, using the gravity of nearby moons to change its course. The European Space Agency will send its Jupiter Icy Moons Explorer in 2022 to study Ganymede, Callisto and Europa, evaluating their potential to support life. Other countries also have their eyes on the giant planet, with China's Gan De proposed for launch in 2029 and an unnamed Russian proposal to use a nuclear-powered tug to travel to the planet sometime after 2030.

Further into the future, Europa is seen as a potential site for human colonisation of the Solar System, as it is geologically stable and levels of radiation are low there. Low is a relative term, however, as unshielded colonists would receive 5.4 sieverts of radiation per day from Jupiter, compared to 0.0024 sieverts per year on Earth. This is still enough to cause radiation poisoning.



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Above: Europa is the target of many space agencies, which are keen to explore its life-hosting potential

EVOLUTION OF THE JOVIAN GIANT

Date: 4.6 billion years ago
Activity: The Solar System began to form from a cloud of gas and dust around a new star

Date: 4.596 billion years ago
Activity: Jupiter and Saturn began to take shape

Date: 2400 BCE
Activity: Babylonians tracked a full cycle of Jupiter's movement across the skies

Date: 270 BCE
Activity: Jupiter was part of Aristarchus of Samos' heliocentric model of the Solar System

Date: 1610
Activity: Galileo discovered the Galilean moons: Ganymede, Callisto, Io and Europa

Date: 1892
Activity: Edward Emerson Barnard discovered a fifth moon of Jupiter, Amalthea

Date: December 1974
Activity: Pioneer 11 passed within 42,500 kilometres (26,400 miles) of Jupiter's cloud tops

Date: January 1979
Activity: Voyager 1 reached the gas giant planet

Date: December 1995
Activity: The Galileo probe entered Jupiter orbit

Date: July 2016
Activity: The Juno probe entered a polar orbit around the planet

JUPITER BY NUMBERS

24,000°C
The estimated temperature at Jupiter's core

11.8 YEARS
Jupiter's orbit around the Sun

5,000KM
The thickness of Jupiter's atmosphere, the deepest in the Solar System

79
known moons circulate around Jupiter

1665
Jupiter's Great Red Spot is a storm known to have existed since at least 1831, and maybe even since 1665

14x
Jupiter's magnetic field is 14 times stronger than Earth's, and the strongest in the Solar System except for sunspots

4TH
Fourth-brightest object in the sky as seen from Earth

> "MUCH SCIENTIFIC INTEREST HAS NOW TRANSFERRED TO THE PLANET'S MOONS"

MYSTERIES OF THE UNIVERSE

WHY DID A STAR NEARLY VANISH FROM THE SKY?

A star close to the heart of the Milky Way dimmed by 97 per cent for 200 days, and no one quite knows how

Reported by David Crookes

© Getty

More than 25,000 light years away, there's an enormous star that's 100 times the size of the Sun. It's in the constellation of Sagittarius, close to the heart of the Milky Way. Yet for about 200 days in 2012, it virtually vanished from the night sky. For those studying stars in this dense region of the galaxy, it was understandably something of a surprise. Astronomers had been working their way through data from the VISTA Variables in the Via Lactea Survey in 2019, but they had certainly not expected to come across anything so perplexing.

What they were witnessing was a dimming on an near-unprecedented scale, with the star, called VVV-WIT-08, decreasing in brightness by a mammoth factor of 30: a staggering 97 per cent. "It's not particularly unusual for stars to dim by a small amount for short periods," says Dr Leigh Smith from Cambridge's Institute of Astronomy. "But it's very unusual for stars to dim as much and for as long as this."

Smith led the discovery, working with other scientists in the UK, Germany, Brazil, Chile and Poland. The data had been gathered by the European Southern Observatory's Visible and Infrared Survey Telescope for Astronomy (VISTA), based at the Paranal Observatory in Chile and the largest in the world to survey the sky in near-infrared wavelengths. The study involved creating a database of the light curves of some 1 billion stars and checking for anything which looked unusual. "A light curve is the sequence of brightness measurements of a star at a series of times, and anything unusual tends to be most interesting," Smith explains. "More often they can indicate problems with the data-processing procedures. In our case, we checked on stars that had a large range in brightness, and VVV-WIT-08 was one of the first in the list. After ruling out a data-processing problem, it was clear that the drop in brightness was real."

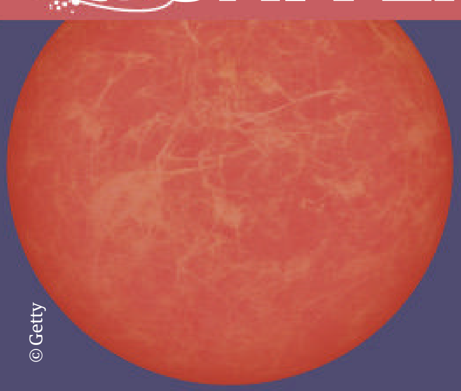
Today, VVV-WIT-08 is back at full brightness. The dimming occurred slowly, fading at the start of 2012 to the point of almost disappearing before gradually recovering. Smith says stars change their brightness because they pulsate or are eclipsed by another star in a binary system. Could either of these explain what's happening?

Prior to the dimming event in 2012, it's unlikely anyone had ever studied VVV-WIT-08. "The star looks exactly like millions of similar giant stars in the Milky Way," Smith says. He adds that he wouldn't be surprised if no one had even looked at the star before his team found it in 2019. "Although the data covering the dimming event existed before then, it needs to be processed, which takes a huge amount of time."

Even so, VVV-WIT-08 had been captured by several observation campaigns covering large parts of the sky, enabling the astronomers to work with earlier brightness measurements in different wavelengths. "Using these, we were able to roughly estimate what kind of star we were looking at," Smith says. "The suggestion was that it's an ordinary giant star, which made the drop in brightness all the more puzzling."

One explanation is that the dimming was caused by an unknown dark object drifting,

TAP HERE TO PLAY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VVV-WIT-08
BY NUMBERS

100x
The star is a hundred times larger than the Sun

25,000
Number of light years from Earth to VVV-WIT-08

2012
Year that the dimming event happened

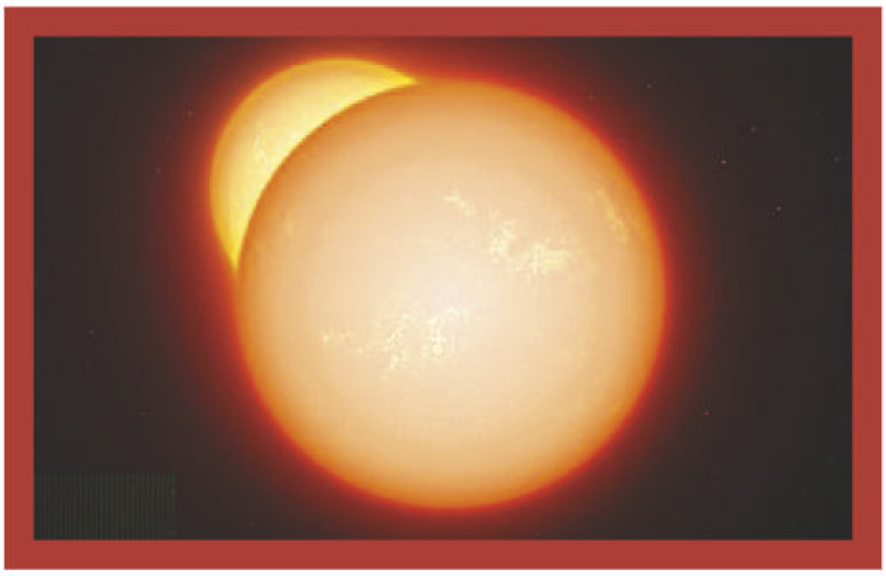
FOUR
long-period eclipsing binaries have been found

17
Number of years VVV-WIT-08 has been observed

ONE
Times the eclipse has been seen so far

8 BILLION
The estimated age of VVV-WIT-08

1 BILLION
Number of stars sampled in the study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Above: TYC 2505-672-1 is the record holder for the longest eclipse and the longest period eclipsing binary, but VVV-WIT-08 may claim the latter when its period is confirmed

Below: VISTA, the Visible and Infrared Survey Telescope for Astronomy, was used to discover VVV-WIT-08

by chance, in front of the giant star. This was dismissed because simulations suggest that an implausibly large number of dark bodies would need to be floating around the galaxy.

It's more likely it was a planet or a companion star orbiting the giant star, but these alone are unable to account for the depth of the dimming. Whatever was causing the dimming was also surrounded by an opaque disc of dust, and this, it was found, had a hard edge – unusual because debris discs tend to taper, thereby begging the question of how the dust is being distributed to make it appear that neat.

It doesn't help that no one has been able to observe VVV-WIT-08's orbital companion, but the data suggests that whatever was hiding the star had to be huge. It managed to block not only visible wavelengths, but infrared ones too. "The obscuring object has to be larger than the giant," affirms Smith. "That much is known for sure, since if it were smaller it could not have blocked as much light as it did." This means that the obscuring object has to be at least half as big as the distance between the Earth and Sun, "but likely much bigger," Smith continues. "Also, because the shape of the dimming is not quite symmetric, we're able to say for sure the object is elongated – that is, it can't appear in silhouette as a circle, as a planet might."

This is why astronomers have considered the presence of a large cloud or a disc, and yet it's not so straightforward. "A cloud would tend to obscure more visible light than infrared, but for VVV-WIT-08 they are obscured by the same amount," Smith explains. "That leaves the disc theory remaining, but while large discs are not uncommon and often occur as a result of star formation, they aren't usually very long-lived. VVV-WIT-08 is relatively old, so the presence of such a disc is quite unusual here."

Astronomers have estimated that the star is 8 billion years old and that it's burning at cooler temperatures than the Sun. In figuring what may have caused such a dramatic dimming, they are also able to draw on some past studies. The red supergiant Betelgeuse, which is one of the ten brightest stars in the night sky, spewed out a huge cloud of dust in 2019, causing it to dim by two-thirds. "There are a handful of examples of stars obscured by discs that are hosted by a gravitationally bound companion, too," says Smith.

He points to the multiple star system Epsilon Aurigae, discovered by German astronomer Johann Heinrich Fritsch in 1821. Its brightness drops by

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SIX POTENTIAL EXPLANATIONS

What could have caused the star to dim?

AN UNKNOWN DARK OBJECT PASSED BY

A simple explanation is that an unknown dark object drifted in front of the giant star, and this just happened to be caught in the data. The astronomers have ruled this theory out, however, because computer simulations show there would need to be "an implausibly large number of dark bodies floating around the galaxy for this scenario to be likely," says Smith.

THE STAR ITSELF WAS SURROUNDED BY DUST

Maybe a circumstellar disc of dust and debris obscured VVV-WIT-08, causing it to dim. But this wasn't seriously considered, says Smith, because it would require huge changes in disc thickness to cause such a large variation in brightness. It would need to be thin outside of the dimming event then as thick as the giant star is large during it. "I wouldn't expect such a disc to be stable long term," he says.

THE STAR WAS OBSCURED BY DUST FROM ELSEWHERE

It's generally felt that the obscuring material is dust. This might be thick enough to let no light through, or it might allow a tiny amount of light through if the grains are large. But grains smaller than a few micrometres would block more visible light than infrared, which doesn't match the observations, says Smith

A BLACK HOLE IS ORBITING THE STAR

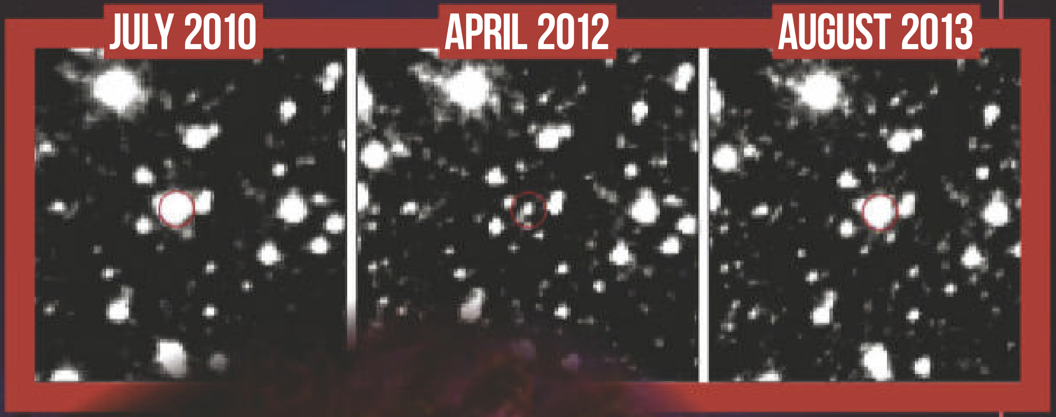
Perhaps an accretion disc around a black hole is to blame for the dimming of VVV-WIT-08. But the researchers' paper talks of a black hole needing to be in the low tens of solar masses – relatively small in black hole terms. Yet X-rays would be emitted, and none were present. Astronomers have never observed a dark, dense debris ring around an orbiting black hole either, so the jury remains out on this one.

IT'S OBSCURED BY MATTER ORIGINATING FROM THE STAR

As a companion object orbited the star, there could have been a mass transfer of matter to it which created a disc. Their current separation is too great to facilitate this – but it might not have been in the past. A transfer of matter such as this would conveniently explain the potential smaller size of the giant star.

IT'S OBSCURED BY MATTER ORIGINATING FROM A COMPANION

There is a possibility that the material blocking the star's light came from an object gravitationally bound to VVV-WIT-08. The material could have come from the companion, ejected when it underwent a supernova explosion. Or it might have been ejected during the less dramatic later stages of its evolution.



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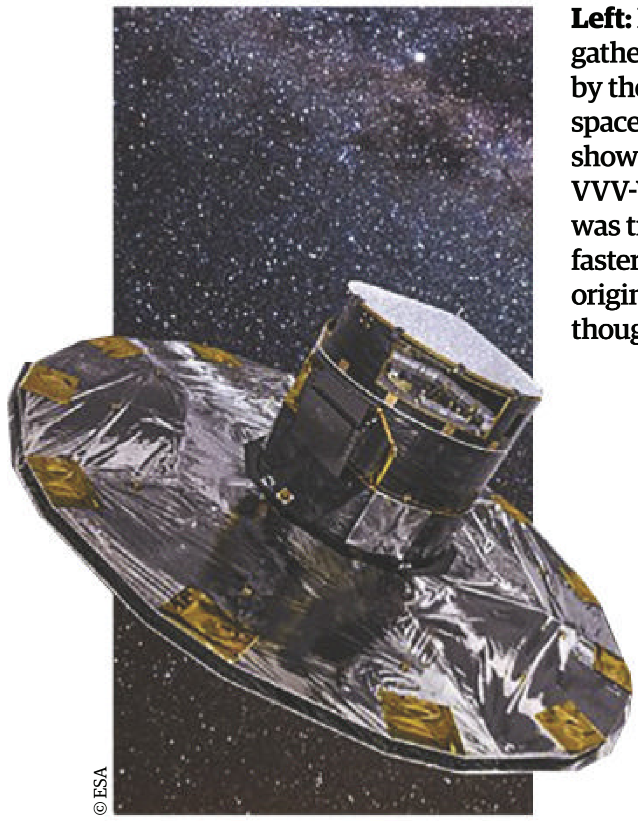
Above: A sequence of images showing how VVV-WIT-08 faded and then brightened again during observations, peaking in April 2012

Left: An artist's impression of binary star VVV-WIT-08

© Amanda Smith, University of Cambridge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Left: Data gathered by the Gaia spacecraft showed that VVV-WIT-08 was travelling faster than originally thought

50 per cent every 27 years, with the dimming lasting between 640 and 730 days. That, however, is significantly less dramatic than the 97 per cent drop of VVV-WIT-08.

"VVV-WIT-08 is equalled in the depth of its dimming by a system called TYC 2505-672-1," Smith says, describing a binary system eclipsed by a disc around its companion star every 69 years. The same goes for two other candidates picked up by Smith's team, VVV-WIT-10 and VVV-WIT-11, and confidence is high that others will be found.

One thing's for sure, it would make life easier if astronomers could foresee when VVV-WIT-08 will dim again. However, as can be seen from Epsilon Aurigae and TYC 2505-672-1, it could be many decades before that happens. All that's known so far is that in 17 years of observations the eclipse of VVV-WIT-08 has only happened once. The next one could happen in ten years. But astronomers go cold at the prospect of not witnessing it again for another 200.

"Having the star return to its former brightness makes it easier to perform follow-up observations. In particular, we'll be able to more easily monitor the giant star's velocity along the line of sight – that is, its velocity towards or away from us, the radial velocity," Smith says. "Having said that, more observations during the dimming event would have been nice. While the giant star is obscured you get more direct observations of the object doing the obscuration."

When the next eclipse happens will depend heavily on the nature of the unseen companion. "The period of its orbit is dependent on its mass," Smith continues. "This means that even if we're never able to directly see the companion, we will be able to infer its mass by measuring the orbital period, and the mass may be all

BLOCKING THE LIGHT

How light from VVV-WIT-08 was prevented from reaching Earth

1 RECONSTRUCTED IMAGE

Data from the Via Lactea survey is used here to show the effect of the occulting disc on the giant star VVV-WIT-08. The star is pictured in the centre, dimmed slightly because the disc is moving across it.

2 THE MYSTERY HOST

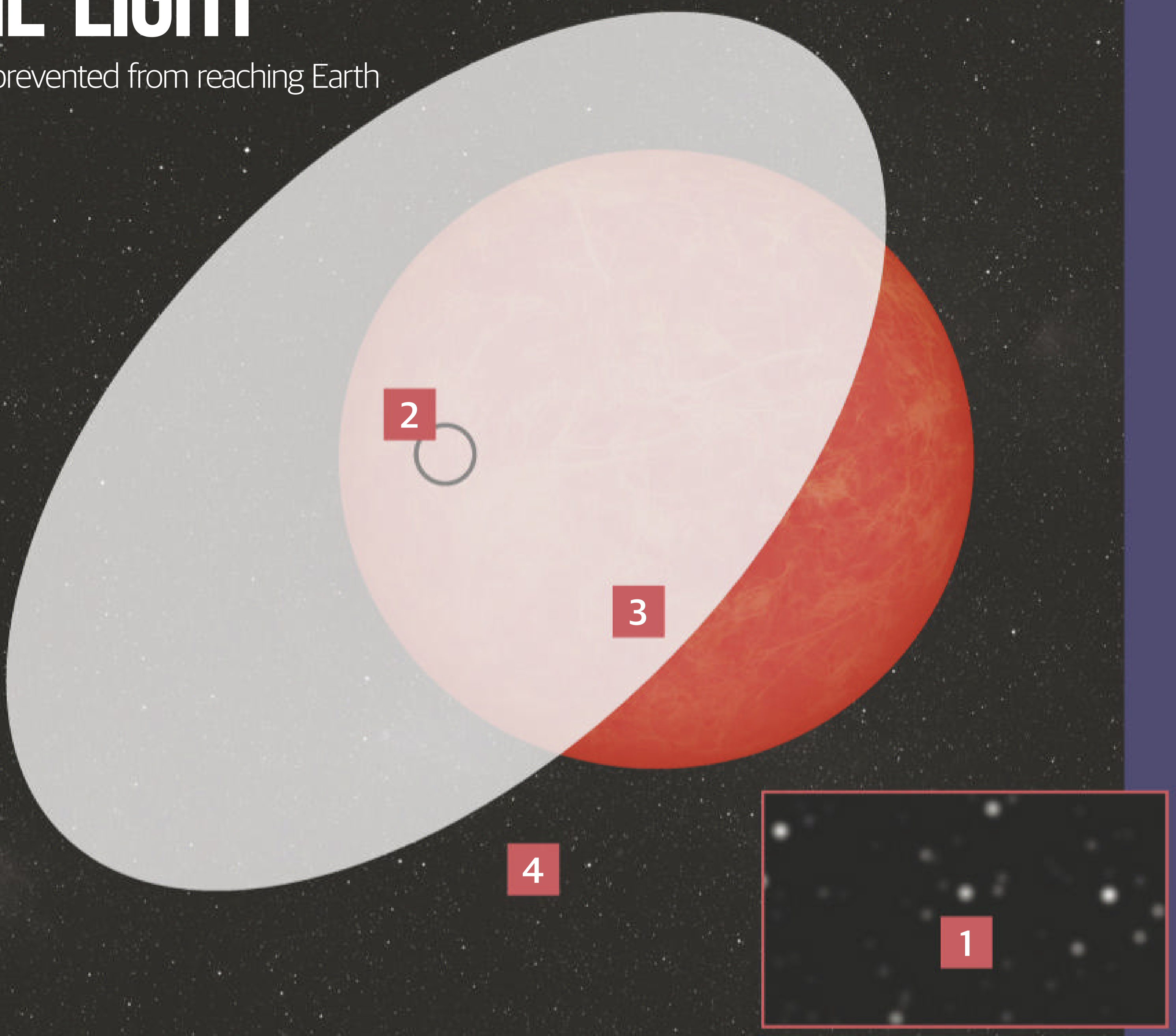
Although the object that has obscured the star when viewed from Earth looks huge, the host itself is much smaller.

3 THE SURROUNDING DISC

The host is surrounded by a huge, opaque disc, illustrated here in grey, and it is this which blocked more than 97 per cent of the star's light.

4 A LONG PERIOD

This reconstruction shows the state of the eclipse in February 2012. It peaked in April and then moved across, allowing VVV-WIT-08 to gradually brighten again in observations.



we need to say for sure what it is." Thankfully, astronomers may not have to wait that long, because the amount of data that could be used to explain what is happening is growing. It'll also be possible to monitor the radial velocity to estimate the period of the orbit long before the next dimming event. "We think we now have enough similar objects that we can start to study their properties as a group, which may lead to some breakthroughs in understanding them," Smith says. "But the origin of the disc material, the nature of the disc hosts and the apparent small size of some of the giant stars are all open questions."

Another conundrum is why, using data from later observations, including the ground-based Optical Gravitational Lensing Experiment (OGLE) and the European Space Agency's Gaia spacecraft, VVV-WIT-08 seems to be travelling faster than anyone had imagined. At this speed it looks like it will one day escape the Milky Way, which is strange for a star in a dense region close to the centre of the galaxy.

"Observing the speed made a huge impact on the study," says Smith. "VVV-WIT-08 moving that fast is highly unlikely. Our estimate of its speed required an estimate of its distance, and for our speed estimate to be too high, our distance estimate must also have been too large.

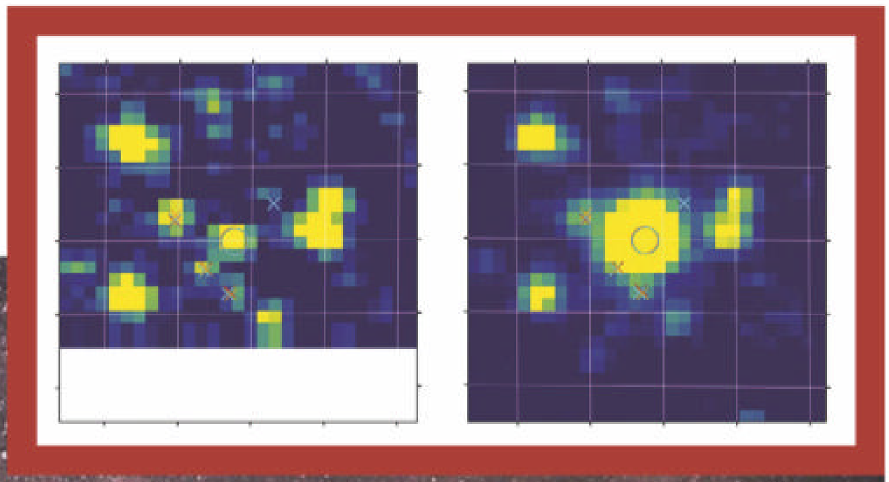
"For the giant star to be closer than it appeared, it must also be smaller than normal, which might end up being a clue towards the nature of the mystery companion. One theory is that the companion has stripped material from the giant star, shrinking the giant star and forming the disc around the companion." But this would only partly explain what has been observed.

The astronomers have certainly left nothing off the table. They've even considered that the orbiting body is a black hole ringed with debris - something never observed before. What they are saying, however, is that VVV-WIT-08 may well belong to a new class - that it's a 'blinking giant' binary star system. This is one of the possibilities put forward in Smith's coauthored paper, published in *Monthly Notices of the Royal Astronomical Society.*

But how did they come to be? No one knows, but Smith and others are determined to get to the bottom of it. VVV-WIT-08 doesn't appear to be alone, either. There are around six potential star systems that could fit into this theorised 'blinking star' category, and the challenge is to work out how they came to be surrounded by discs even though their orbits are so far from the giant star - indicated by the amount of time that is passing for the eclipse to occur again. "We have so much more to discover," Smith says.

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

Below: The image on the left shows VVV-WIT-08 three days before minimum flux. The one on the right is two years later



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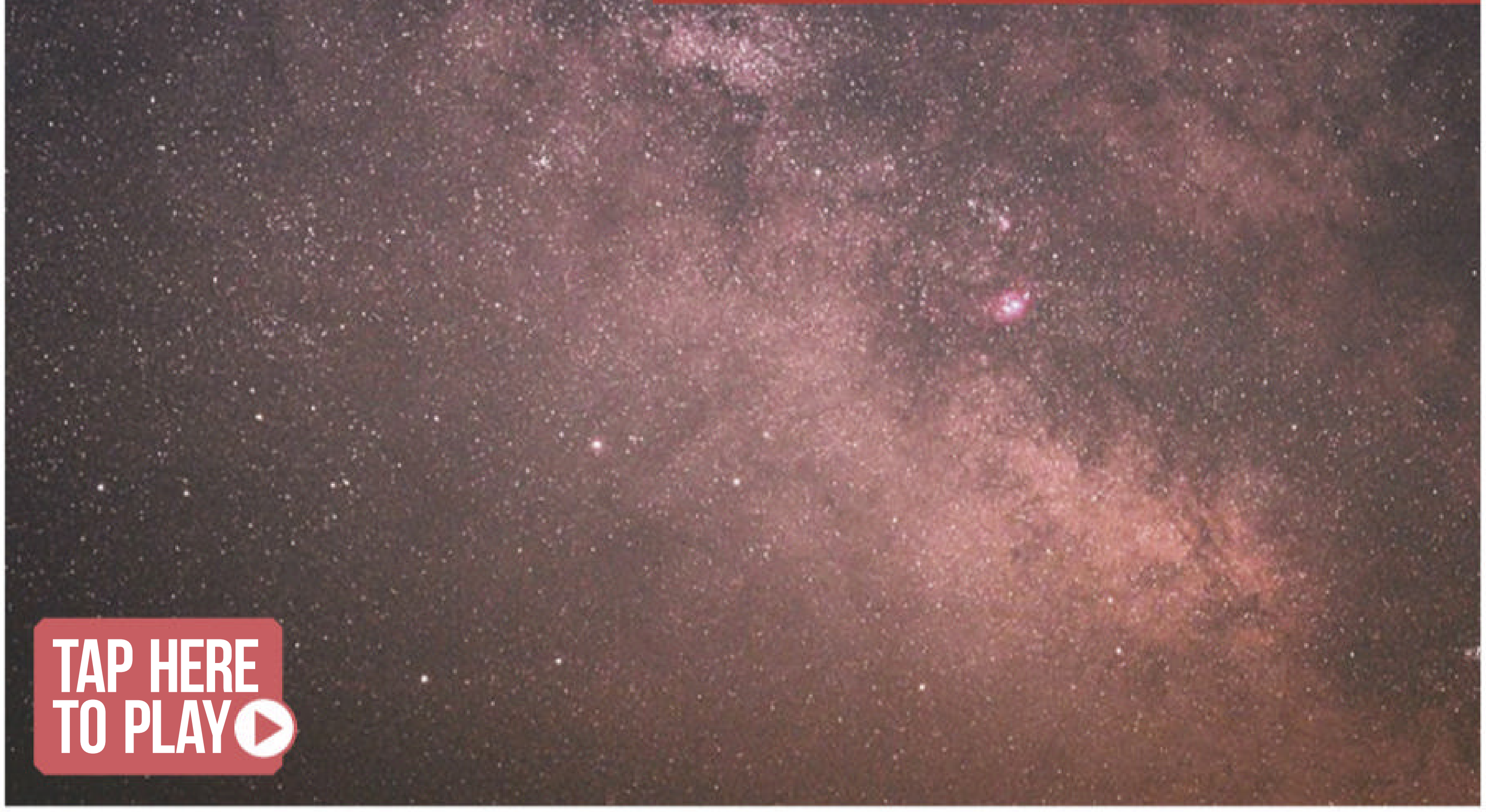
Bottom: VVV-WIT-08 is in the Sagittarius region of the Milky Way, close to the galaxy's heart



Source: Wikipedia Commons © Spark802

OTHER STELLAR VANISHING ACTS

How does VVV-WIT-08 compare with other long-lasting stellar eclipses?

TYC 2505-672-1

Distance from Earth:
10,000 light years

Time cycle:
Every 69 years

Duration of near total eclipse:
Three-and-a-half years

Dims by:
98.4 per cent

Next eclipse due:
2080

© Jeremy Teaford, Vanderbilt University

EPSILON AURIGAE

Distance from Earth:
2,200 light years

Time cycle:
Every 27 years

Duration of near total eclipse:
640 to 730 days

Dims by:
50 per cent

Next eclipse due:
2036

© NASA

VVV-WIT-08

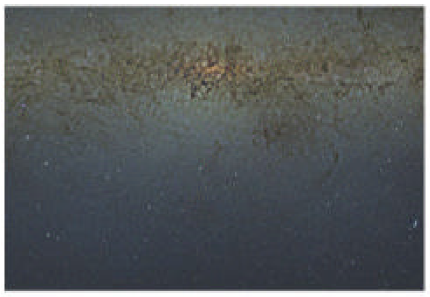
Distance from Earth:
25,000 light years

Time cycle:
Unknown

Duration of near total eclipse:
200 days

Dims by:
97 per cent

Next eclipse due:
Unknown



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HUNT FOR LIFE

What makes the TRAPPIST-1 system an interesting target for exoplanet research?

TRAPPIST-1 is unique because it is currently the only system for which we could probe the atmospheres of planets that are similar to Earth in terms of size, mass and irradiation received from the star. This facilitated access to small planets is enabled by the size of the host star, which is only marginally larger than our Solar System's Jupiter.

This remarkable trait makes it 100 times easier to detect the atmospheres of planets orbiting TRAPPIST-1 compared to the same planets orbiting a Sun-like star. While the diminutive nature of the TRAPPIST-1 star renders it very faint, it is not a limitation for large space observatories, such as the upcoming James Webb Space Telescope (JWST) that is scheduled for launch later this year.

We will learn a lot about the seven planets of the TRAPPIST-1 system with the JWST. No less than seven different science programs will be using the full range of JWST instrumentation to scrutinise the surfaces and atmospheres of these Earth-sized planets to determine their make-up.

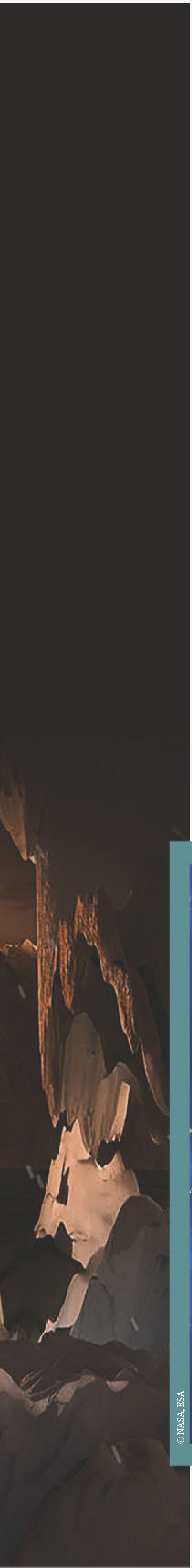
These new insights will enable us to better understand the formation pathways of planets that are similar to our own Earth. As usual in astronomy, we ought to look afar in order to learn about our very own origins.

Brice-Olivier Demory, SAINT-EX research group, University of Bern

Below: TRAPPIST-1 lies 39.5 light years from Earth and has seven planets in orbit

© NASA/JPL-Caltech

> "AS USUAL IN ASTRONOMY, WE OUGHT TO LOOK AFAR IN ORDER TO LEARN ABOUT OUR VERY OWN ORIGINS"
>
> BRICE-OLIVIER DEMORY



Did you know?

Sagittarius A* is around 26,000 light years from our Solar System - we don't need to worry about falling in!

ASTROPHYSICS

Will Sagittarius A* eventually consume the Milky Way?

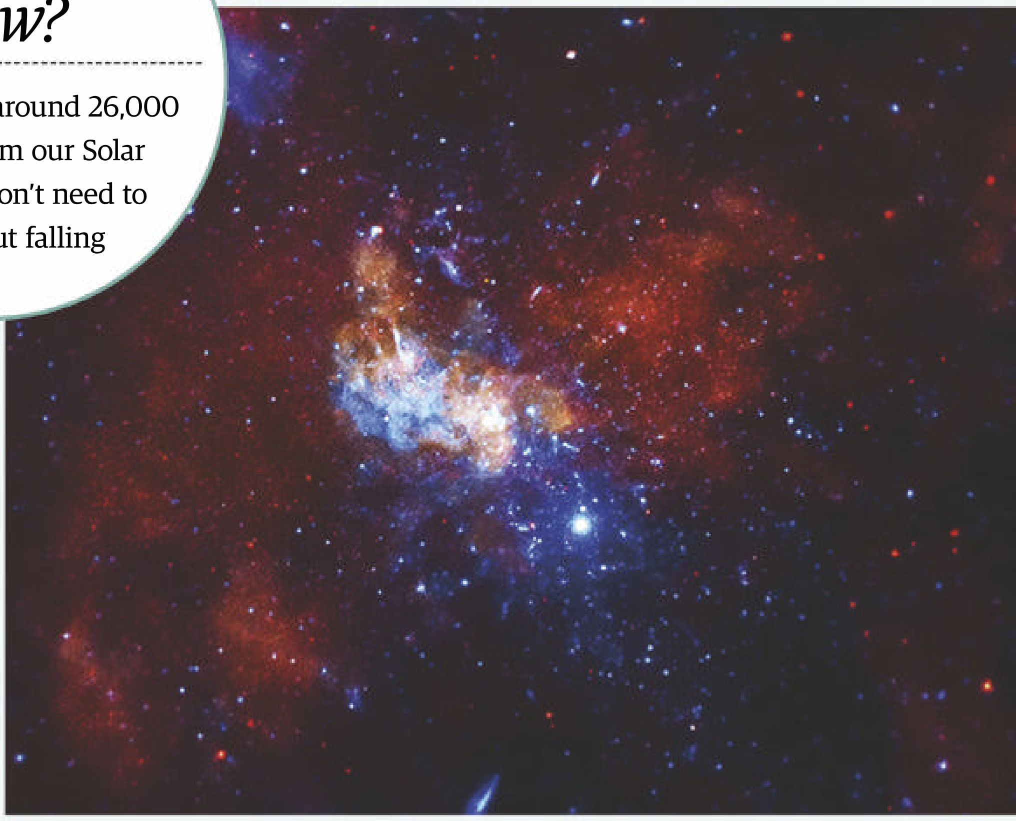
The short answer is no. The gravitational pull of Sagittarius A* is simply not enough to consume the Milky Way on its own. The laws of gravity are such that gravity doesn't care about the object causing the gravitational pull, just about its mass.

If we replaced the Sun with a black hole with the same mass, and a radius of approximately three kilometres (1.8 miles), nothing would happen - besides us not getting sunlight anymore. Earth would keep rotating around the Sun as it does now, not knowing that the Sun has turned into a black hole as its mass has remained the same. To be consumed by a black hole, you would have to plunge straight into it, which is somewhat akin to finding a needle in a haystack.

Much more concerning for us is the fact that in less than 5 billion years, our Milky Way will collide with our neighbouring galaxy Andromeda, which at its centre hosts a supermassive black hole 100 times more massive than Sagittarius A* - therefore 100 times as large.

However, even in this extreme case the probability of this black hole swallowing the Milky Way is still pretty low.

Sunny Vagnozzi, Newton-Kavli fellow at the University of Cambridge's Institute of Astronomy



© NASA

Above: Sagittarius A* was first detected as radio signals by Karl Jansky

Below: Though dark matter is invisible, its influence can be seen

© NASA, ESA

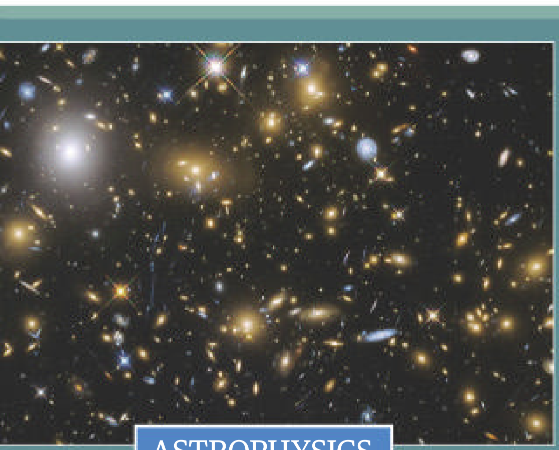
ASTROPHYSICS

How is dark matter located if we can't see it?

Dark matter is invisible, but gives itself away by moving other things. Look out of your window: are the trees moving? You can't see the wind, but it must be blowing because leaves are twitching. Stars and galaxies are leaves in the cosmic wind. The distance between galaxies was gradually controlled after the Big Bang by the gravitational tug from dark matter. The largest clumps of dark matter still fling galaxies around today, faster than galaxies could move if pulled only by each other's gravity.

A clump of dark matter in our Milky Way whips individual stars into fast orbits. Smaller clumps of dark matter have pulled stars away from streams that used to be orbiting together. The cosmic soup is lumpy. But the lumpiness depends on its ingredients. If dark matter feels forces other than gravity, or is made of certain particles, lumps just smaller than those known would have dissolved. To learn what dark matter is, we are watching ever more sensitive leaves - faint stars and even rays of light - for the indirect flutter of the tiniest passing breeze.

Richard Massey, Institute for Computational Cosmology, Durham University



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Left: Every galaxy is held together by its own gravity

Right: The bow shock is an effect of Earth's magnetic field

ASTROPHYSICS

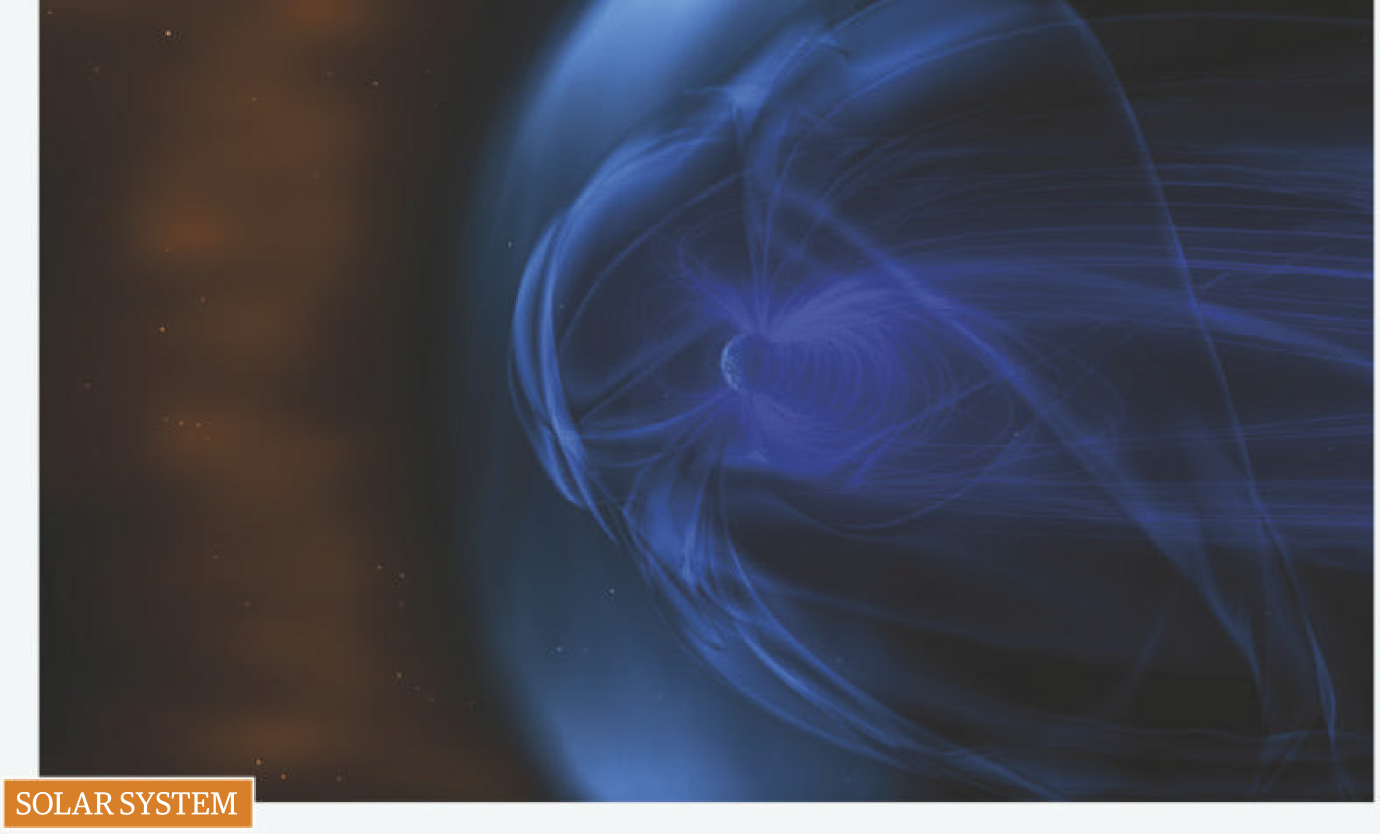
Can a galaxy ever split apart into multiple galaxies?

The quick answer is no! The quick reason why is because gravity sticks them together so strongly they would be impossible to tear apart. The explanation comes down to gravity. Most big things in the universe - like planets, stars and galaxies - are held together by gravity. The Earth stays together because the atoms that make up our planet all pull towards each other, and pulling them apart would take energy.

If you were a supervillain who wanted to destroy the Earth, you'd need to put in enough energy to overcome that gravitational attraction. The amount of energy that you'd need to use to pull something apart is called the 'gravitational binding energy'.

The gravitational binding energy of our Milky Way is around 10^{54} joules - that's a one followed by 54 zeros! This is how much energy you'd need to put in if you wanted to split our galaxy apart. We can even use the most famous equation in science - $E=mc^2$ - to work out how much energy this is. It turns out that you'd have to vaporise 10 million suns into pure energy to split apart a galaxy. Fortunately, this is probably beyond even the most nefarious supervillain. .

Matt Bothwell, University of Cambridge



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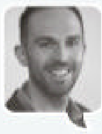
SOLAR SYSTEM

What causes Earth's bow shock?

Earth's magnetic field acts as an obstacle to the solar wind, meaning this plasma streaming from the Sun needs to be deflected around our planet. But because the solar wind is supersonic, the only way this can occur is through a shock wave known as the bow shock.

A shock wave is an extreme sound wave where the pressure (density and temperature) has built up, forming a sharp jump in values over a short amount of distance. Earth's bow shock borrows its name from an analogous effect for boats: when a boat travels through water its bow (front) pushes the water out of the way, but if the boat is travelling faster than the speed of the water waves the water will pile up, forming a shock.

The sonic boom around jet fighters is another example of the same effect. While most people think of shock waves as a bad thing due to their destructive role in explosions, Earth's bow shock - as well as those for boats and aircraft - actually protects us. By slowing down and deflecting many of the charged particles from the Sun away from us, the bow shock helps prevent this ionising radiation from bombarding our planet



Martin Archer, Stephen Hawking fellow at Imperial College London

STARS

What causes a solar flare?

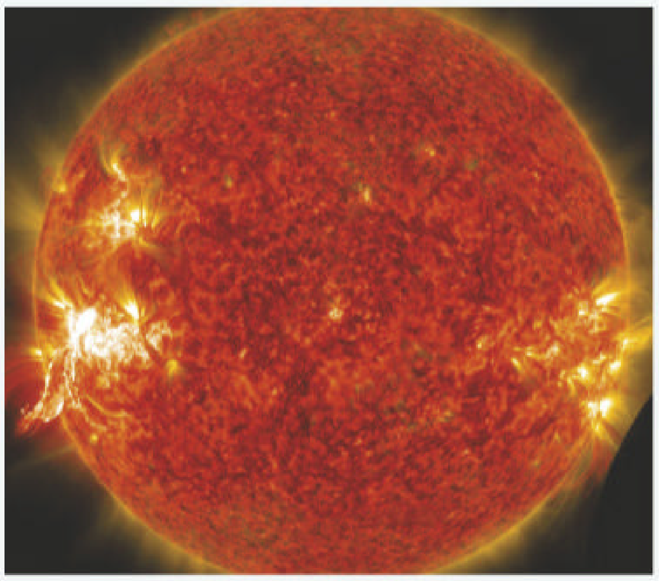
Solar flares originate from highly complex and unstable strong magnetic fields that arc out over sunspots. Flares are driven by the so-called magnetic reconnection process between opposite-polarity magnetic fields. The magnetic field lines can meet, fuse and also break apart to create new connections.

During the reconnection process, the released magnetic energy is converted into kinetic energy, thermal energy and particle acceleration that manifests in a burst of radiation across a wide range of the electromagnetic spectrum, from radio waves, through optical emission to X-rays and gamma rays.

Solar flares erupt outwards with speeds of up to a few million miles an hour, releasing massive amounts of energy. This can be equivalent to millions of nuclear bombs exploding simultaneously. Flares are categorised according to their brightness in X-ray wavelengths. The most powerful eruptions are X-class flares, which can trigger radio blackouts on Earth, and result in long-lasting radiation storms in Earth's upper atmosphere. An M-class flare is about ten times weaker than an X-class one. These flares could cause brief radio blackouts that affect only Earth's polar regions. The X- and M-class flares are often accompanied by coronal mass ejections (CMEs) that hurl enormous clouds of superheated plasma into space. Compared to X- and M-class events, C-, B- and A-classes are small, without any noticeable consequences on Earth.

Marianna Korsos, research assistant at Aberystwyth University

Right: Solar flares range in intensity depending on the solar cycle



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COSMOLOGY

What are X-ray binaries?

An X-ray binary has a compact object, like a stellar black hole or a neutron star, and a companion star that is normal like our Sun. The compact object and the companion orbit around each other, bound together by gravity, and they're close enough that the compact object slowly eats its friend. As it drains material from the companion and gathers it together to eat it, this material gets hotter than the surface of the Sun and shines very bright X-ray light.

How the compact object eats its companion depends on how massive the companion is. If the star is bigger than our Sun, it will have big clouds of wind coming off it, and as the compact object passes through the wind, it gobbles up the gas in its path. We cleverly named these systems 'high-mass X-ray binaries'. If the companion is smaller than our Sun, then the compact object swirls the star's gas around itself, as if the compact object is sitting in the middle of its own dinner plate. This swirling plate of gas is called an accretion disc, and these systems with small companions are called 'low-mass X-ray binaries'.

Abbie Stevens, Michigan State University & University of Michigan

Below: These pairs can be detected thanks to the X-rays emitted as the smaller star is eaten

© ESA

Did you know?

An X-class solar flare occurred on 3 July 2021 and was the most extreme flare observed since 2017.

EXPLORE THE MILKY WAY

Be a cosmic tourist and take **All About Space**'s tour of our home galaxy

It's easy to forget the true beauty and splendour of the Milky Way. With acres of countryside being torn apart in favour of cities, the change in our planet's landscape can only really mean one thing in this regard: light pollution. This yellow to orange hue plagues many astronomers by washing out the stunning gems that our night sky has to offer, with only the brightest objects managing to shine through the haze. And with the added appearance of the bright Moon, it can be very tough to get any observing done that a stargazer feels satisfied with. The fainter and somewhat delicate beauty of our Milky Way galaxy simply can't compete.

Leaving behind the dazzling, bright lights on a Moonless night, our galaxy will be less obscured. And the sights - particularly over the next few weeks - are ones that will make your jaw drop as our galaxy truly reveals all that it's got.

Allowing your eyes 20 minutes to adjust to the darkness, what you'll see will be a faint band of light, akin to a backlit cloud, snaking its way through a backdrop of stars. Your eyes alone can't resolve the Milky Way into individual stars, but that just makes our galaxy all the more alluring when it comes to hunting for the galactic treasures hidden in the Orion Spur - the section of the spiral arm where we live.

Which sections of the Milky Way you're able to see really depends on your location, as well as the time of year. Throughout July, for example, those in the Southern Hemisphere will find the centre of the Milky Way overhead, its silvery band running from the southwestern horizon to the northeast. In the Northern Hemisphere the centre of the Milky Way is low in the southern sky, its dusty path sweeping upwards in an arch across the eastern sky through to the northern horizon. What's more, some of the Milky Way appears quite mottled, with brighter parts appearing as bursts of star-concentrated clouds interspersed with holes, or clouds of interstellar dust blocking our view of the stars beyond.

What's great about the Milky Way is that you don't need any optical aid to enjoy its true beauty. A dark site and just your eyes can allow you to take in the stunning expanse of our galaxy in all its glory.

© Alamy

> “WHAT YOU’LL SEE WILL BE A FAINT BAND OF LIGHT SNAKING ITS WAY THROUGH A BACKDROP OF STARS”

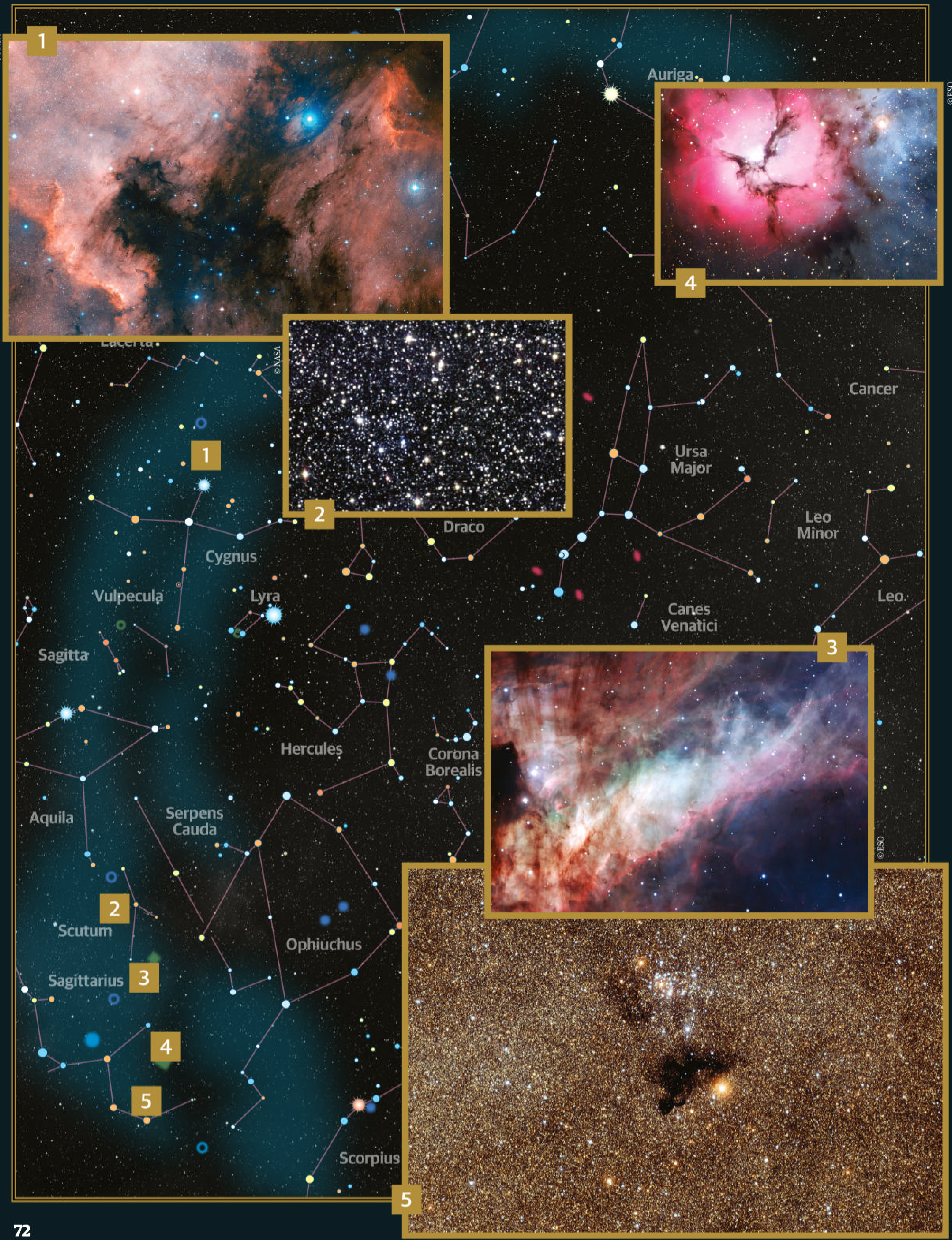
GETTING THE BEST VIEWS OF THE MILKY WAY

You’ll need…

- ✓ A MOONLESS NIGHT
- ✓ DARK SKIES WITH NO LIGHT POLLUTION
- ✓ YOUR NAKED EYE, BINOCULARS OR A TELESCOPE

DON’T FORGET!

It’s difficult to observe the Milky Way in spring from the Northern Hemisphere since it’s very low down on the horizon.



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THE SUMMER MILKY WAY

Despite the shortage of night hours, the middle of our galaxy takes centre stage for a spellbinding sight during the warmer months

If you can observe from somewhere dark, then the summertime Milky Way is one of the most spectacular sights you will ever see in the night sky. The further south you go the better, because the brightest parts of the Milky Way are found in southern constellations such as Sagittarius (the Archer) and Scorpius (the Scorpion). If you are able to travel to locations such as Florida or the Canary Islands on holiday in summer and venture out to a dark site with no light pollution, you'll be stunned at how bright the Milky Way appears. It will look like shimmering clouds rising up from the horizon.

The first thing that you'll notice is that there is structure in the Milky Way: parts that are brighter, and some parts that are dark with barely any stars at all. These are called dark nebulae. They may look like holes in space, but they're not - they are huge clouds of cold gas and dust, cocoons inside which baby stars are being nurtured.

The very centre of our galaxy is in the direction of Sagittarius. We can't see it because the stars, dust and gas of the Milky Way in front of it block our view. As it climbs north, the Milky Way enters the Summer Triangle, an asterism made up of three bright stars - Deneb of Cygnus (the Swan), Altair in Aquila (the Eagle) and Vega in Lyra (the Harp) - which mark the corners of the distinctive triangle.

1 NORTH AMERICA NEBULA (NGC 7000)

Constellation: Cygnus
Right Ascension: 20h 59m 17s
Declination: +44° 31′ 44″
Magnitude: +4.0
Minimum optical aid: 10x50 binoculars or a four-inch telescope

Most objects in the night sky only look tenuously like the things they're named after, but the North America Nebula is the spitting image of the continent - it even has a curved gap that resembles the Gulf of Mexico. In reality it is an emission nebula approximately 2,200 light years away that is forming stars. It is bright, but large and diffuse, so despite being magnitude +4.0 it is very difficult to see with the naked eye, and ideally you need to view it through an instrument with a field of view of at least three degrees to encompass it all: 10x50 binoculars or a four-inch scope should do the trick.

2 MESSIER 26

Constellation: Scutum
Right Ascension: 18h 45m 18s
Declination: -9° 24′ 00″
Magnitude: +8.0
Minimum optical aid: Six-inch telescope

This is an open cluster, which is a loose grouping of young stars that formed together. It is 5,003 light years away, but can be difficult to spot amid the crowded star fields of the Milky Way. In a telescope at high-power magnification, you will be able to resolve up to 25 stars. Look closely and you may also be able to make out the long lanes of dark nebulae around the cluster.

> "THE FURTHER SOUTH YOU GO THE BETTER; THE BRIGHTEST PARTS OF THE MILKY WAY ARE IN SOUTHERN CONSTELLATIONS"

3 THE SWAN NEBULA (MESSIER 17)

Constellation: Sagittarius
Right Ascension: 18h 20m 26s
Declination: -16° 10′ 36″
Magnitude: +6.0
Minimum optical aid: Four-inch refractor or five-inch reflector

Near Sagittarius' border with the constellation of Scutum (the Shield) lies this emission nebula, which is another star-forming zone and one of the best in the sky, but because it is so low when seen from the UK, it loses some of its splendour. It's sometimes called the Omega Nebula because in a modest telescope at low magnification it looks a bit like a ghostly Greek letter Omega.

4 TRIFID NEBULA (MESSIER 20)

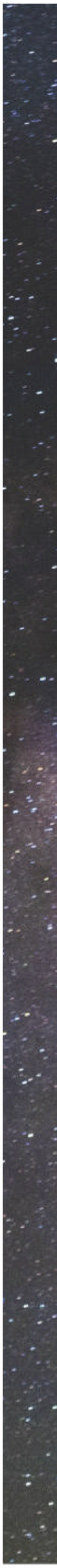
Constellation: Sagittarius
Right Ascension: 18h 02m 23s
Declination: -23° 01′ 48″
Magnitude: +6.3
Minimum optical aid: Five-inch telescope

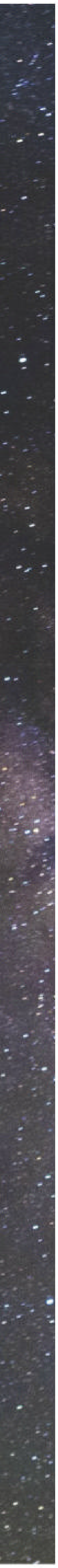
The Trifid Nebula was named by Sir John Herschel, son of William, who saw the nebula divided into three lobes by dark dust lanes - but there are actually four lobes. The Trifid is a mixture of three types of nebulae: an emission nebula (the redder areas), a reflection nebula (the blue regions) and dark nebulae that divide the lobes. Emission nebulae glow when heated by hot stars, while reflection nebulae reflect the light of bright stars.

5 BARNARD 86 AND NGC 6520

Constellation: Sagittarius
Right Ascension: 18h 03m 48s
Declination: -27° 53′ 00″
Magnitude: +9.0 (NGC 6520)
Minimum optical aid: Four-inch refractor or five-inch reflector

Barnard 86 is a classic example of a dark nebula, made of gas clouds filled with impenetrable black dust. It lies next to the open cluster NGC 6520 to the east. Try observing the pair together through your telescope using a magnification of 100x.





THE AUTUMN NIGHT SKY

As the leaves begin to fall from the trees, the summer constellations give way to those of the cooler months

Moving upwards, away from the summer constellations of Cygnus and below, the Milky Way begins to lose some of its lustre as it starts to thin out compared to the densely star-packed region around the galaxy's centre. It is still impressive to see though, especially if you can get out to a dark-sky site in order to observe this shimmering belt of stars.

During autumn our Milky Way moves through the constellations of Perseus, Cepheus (the King) and Cassiopeia (the Vain Queen). Not all of the constellations of summer have disappeared though - the likes of Cygnus and Aquila are still on show, offering observers in the Northern Hemisphere a selection of summer nebulae and star clusters. Autumn is the time to seek out open star clusters in our galaxy, which glow extremely brightly like gems in the night sky.

Astronomy is best done under night skies untouched by light pollution and on a Moonless night, but if you're an urban dweller who is unable to get out to the countryside, open clusters are still easily visible from locations of moderate town haze. Star clusters stand out much better than fuzzy and often dim nebulae. Not only that, but the Milky Way laces through constellations that are high up in the sky, meaning that you won't need to peer through a horizon touched by artificial lighting in order to get a good look at our galaxy.

6 MESSIER 52

Constellation: Cassiopeia
Right Ascension: 23h 24m 48s
Declination: +61° 35′ 36″
Magnitude: +6.9
Minimum optical aid: 10x50 binoculars

This open cluster displays one of the biggest problems of the Milky Way. Because we're looking into the galaxy's spiral arms, which are full of dust, the light of objects in the Milky Way can be dimmed by that dust, which makes it hard to calculate their distance. Open cluster Messier 52 lies between 3,000 and 7,000 light years from us, but even though interstellar dust is blocking some of the light, it's still an easy binocular object.

7 MESSIER 103

Constellation: Cassiopeia
Right Ascension: 01h 33m 20s
Declination: +60° 42′ 00″
Magnitude: +7.4
Minimum optical aid: Four-inch refractor or five-inch reflector

Another open cluster, Messier 103 contains about 40 stars, including a red giant, which is an evolved star reaching the end of its life. This is a very rare sight in an open cluster of young stars. To find M103, locate the bottom-left star of Cassiopeia's 'W', called Ruchbah, or Delta Cassiopeiae, and the cluster is about a degree northeast.

8 MESSIER 34

Constellation: Perseus
Right Ascension: 02h 42m 10s
Declination: +42° 46′ 00″
Magnitude: +5.5
Minimum optical aid: 10x50 binoculars and four- or five-inch telescopes

If you look two binocular fields north of Algol, the brightest star in Perseus and a variable star, you'll come across the open star cluster Messier 34. Binoculars will not resolve any of the 90 member stars, but if you direct a small four-inch telescope its way, the stars will start to pop out.

9 IC 1396

Constellation: Cepheus
Right Ascension: 21h 36m 23s
Declination: +57° 19′ 59″
Magnitude: +11.5
Minimum optical aid: CCD camera

In order to see IC 1396, a star-forming region that forms part of the Cepheus Bubble, you'll need a CCD camera. Being incredibly faint, you would likely find it difficult to pick up this nebula and its darker regions, known as Bok globules, with binoculars or a telescope alone. Imaging IC 1396 will reveal a hot supergiant illuminating its centre and yellow supergiant Mu Cephei at its edge.

10 LITTLE DUMBBELL NEBULA (MESSIER 76)

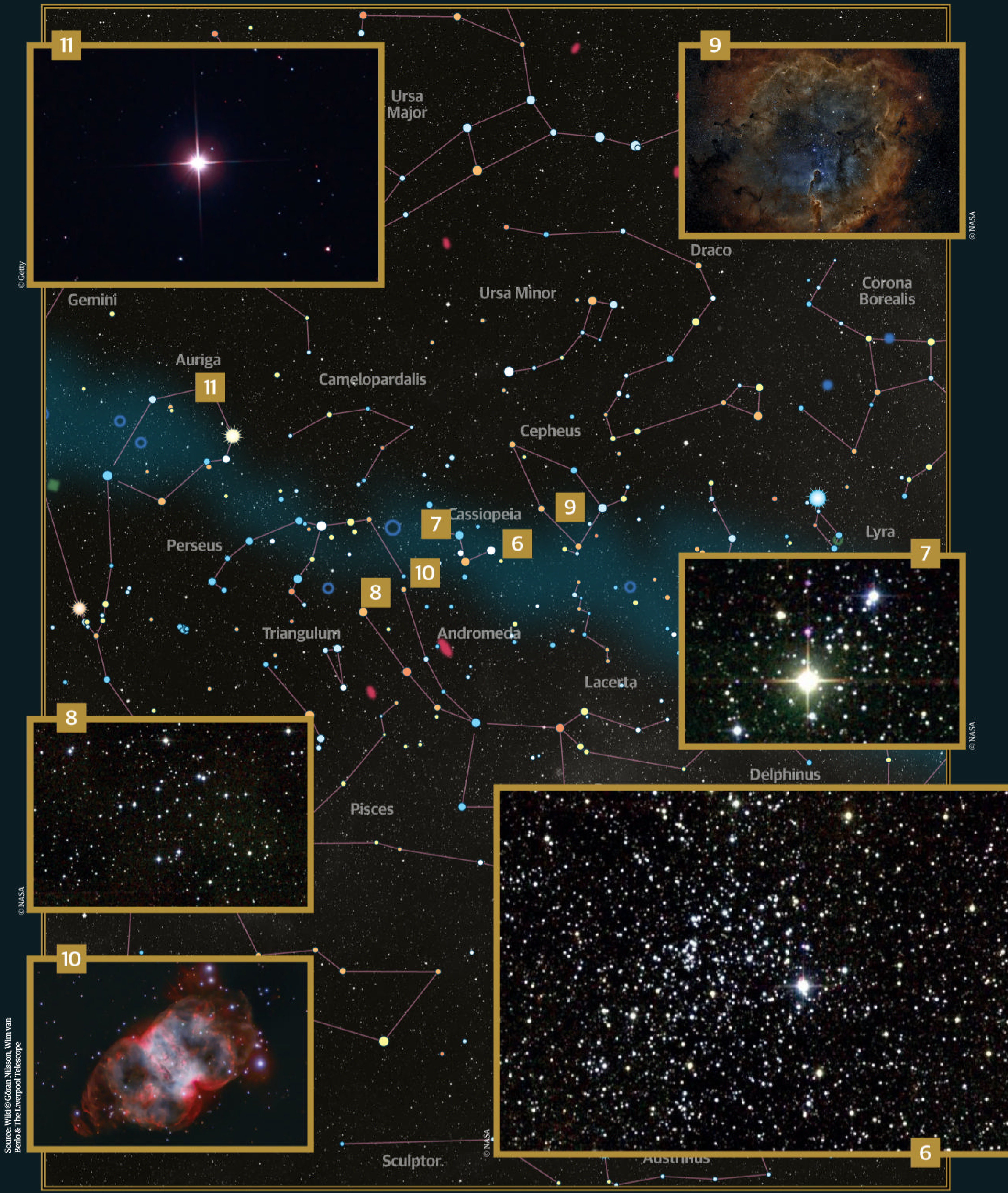
Constellation: Perseus
Right Ascension: 01h 42m 24s
Declination: +54° 34′ 31″
Magnitude: +10.1
Minimum optical aid: Six to eight-inch telescopes

Taking on an appearance similar to that of the Dumbbell Nebula, Messier 27, the pint-sized Little Dumbbell Nebula will require a telescope of at least six inches for comfortable observing. Point your instrument to Phi Andromedae, a prominent blue star, then look slightly east and you will come across the nebula.

11 CAPELLA (ALPHA AURIGAE)

Constellation: Auriga
Right Ascension: 05h 16m 41s
Declination: +45° 59′ 53″
Magnitude: +0.08
Minimum optical aid: Naked eye

It's not too difficult to find the rich, yellow-white star Capella, the sixth-brightest star in the sky, in the constellation of Auriga (the Charioteer). Capella is actually a star system of four stars, which can easily be split into two stars. The yellowish tint of this star is much more apparent in a daytime sky with its contrast against the blue.



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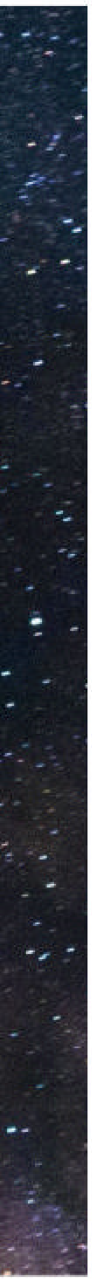


OUR WINTER GALAXY

We reach the outer edge of the Milky Way as we hit the darker days

During the much colder months of the year, we can enjoy the longer hours of the night for extended tours and observations of targets in the night sky. Sadly, winter isn't the best time of year to observe the Milky Way, as our planet looks towards the sparser regions of our galaxy - the outer portion of the disc.

However, that's not to say that the Milky Way doesn't hold a degree of wonder during the winter. Stars still clump together in the splash of white that's characteristic of our galaxy as it laces through the constellations Canis Major (the Great Dog), Monoceros (the Unicorn), Orion (the Hunter) and Puppis (the Poop Deck), bringing with it a spectacular selection of objects for stargazers to enjoy.

12 MESSIER 47

Constellation: Puppis
Right Ascension: 07h 36m 36s
Declination: -14° 30′ 00″
Magnitude: +4.2
Minimum optical aid: Naked eye

It's possible to view the coarse brightness of this open star cluster with the naked eye under very good night-sky conditions. However, the 50 stars found within the cluster won't be resolved so easily without the assistance of a pair of binoculars or a small telescope. Messier 47's swarm of young stars takes over a portion of the night sky around the same size as the full Moon.

13 ROSETTE NEBULA AND NGC 2244

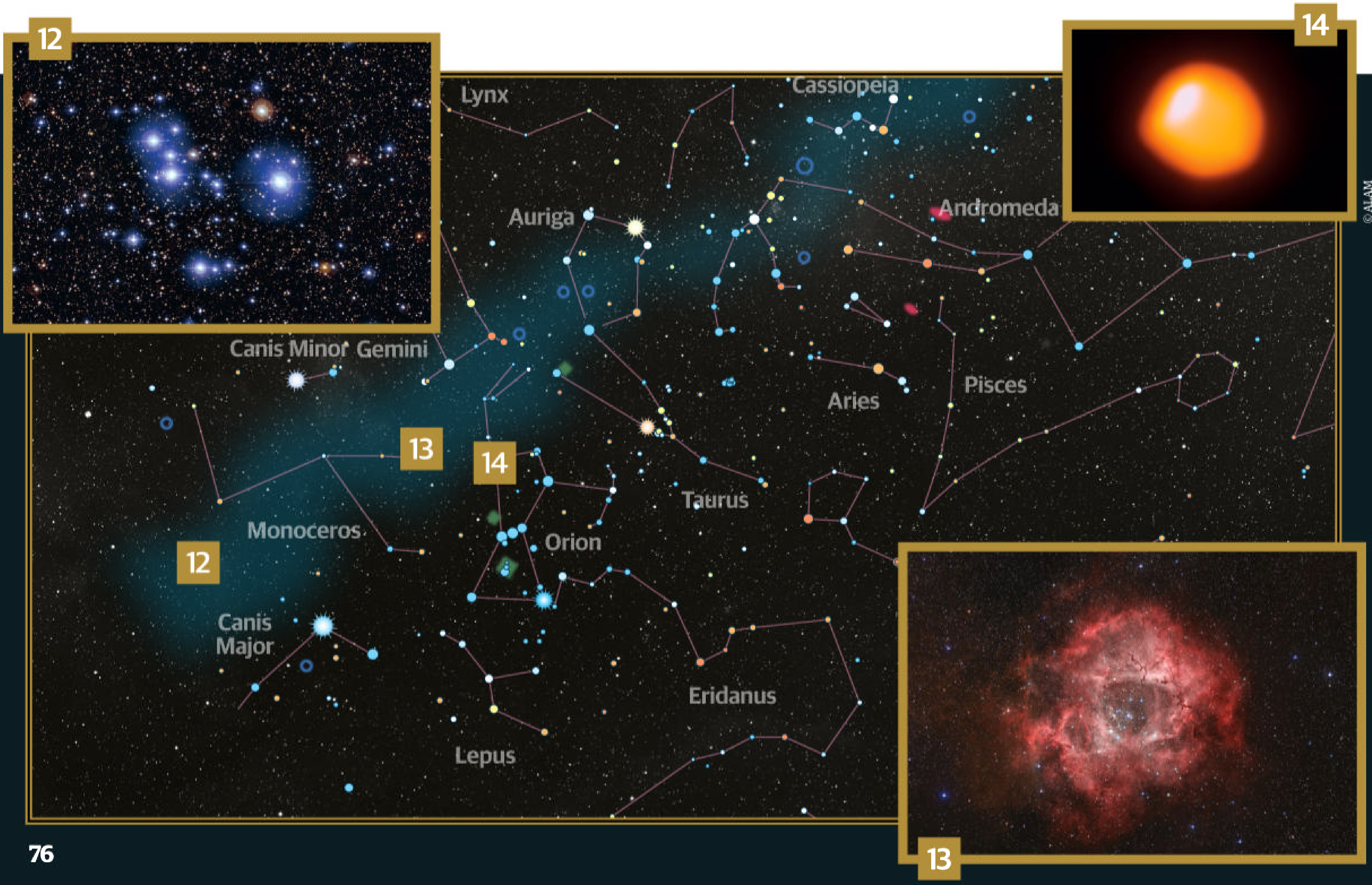
Constellation: Monoceros
Right Ascension: 06h 33m 45s
Declination: +04° 59′ 54″
Magnitude: +9.0 (Rosette Nebula), +4.8 (NGC 2244)
Minimum optical aid: 10x50 binoculars

The Rosette is a giant ring nebula in Monoceros, and NGC 2244 is a young star cluster that has emerged from that nebula. Spotting the cluster is easy in binoculars or a small telescope, but seeing the nebula visually is difficult without a large telescope, dark sky and ultra-high-contrast filter.

14 BETELGEUSE (ALPHA ORIONIS)

Constellation: Orion
Right Ascension: 05h 55m 10s
Declination: +07° 24′ 25.42″
Magnitude: +0.2 to +1.2
Minimum optical aid: Naked eye

It's not hard to spot the orange-red hue of the ninth-brightest star in the night sky. You can use a telescope or binoculars to view red giant Betelgeuse, but you'll see nothing more than you can with the unaided eye.



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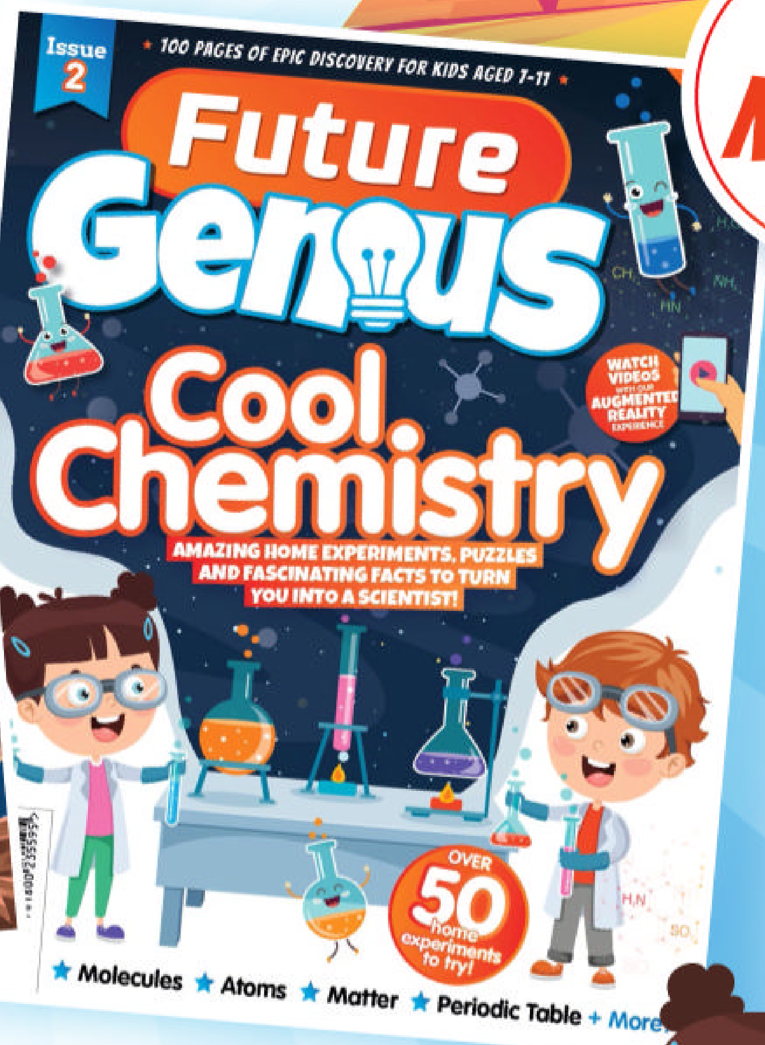
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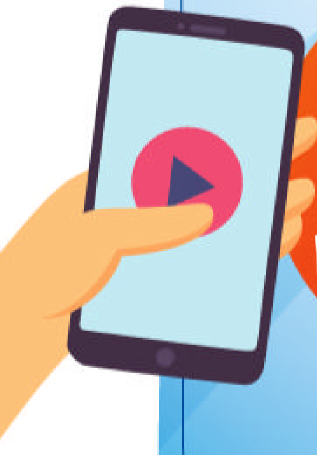

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WHAT'S IN THE SKY?

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> "THE START OF OUR OBSERVING PERIOD IS THE PERFECT TIME TO SPOT SOME PERSEIDS"

RED LIGHT FRIENDLY

In order to preserve your night vision, you should read our observing guide under red light

© Getty

12 AUG
The Perseid meteor shower produces its peak rate in the constellation of Perseus

20 AUG
Jupiter reaches opposition in Capricornus, glowing at magnitude -2.9

20 AUG
The Moon and Saturn pass within 3°42' of each other in Capricornus

22 AUG
Conjunction between the Moon and Jupiter in Capricornus at a separation of 3°57'

22 AUG
The full Moon reaches full phase, and is visible for much of the night

30 AUG
The Moon passes its last quarter phase and is visible 57° above the southeastern horizon

1 SEP
The Aurigid meteor shower reaches its peak of around five meteors per hour

1 SEP
Mercury is at its highest altitude, shining at magnitude +0.1

JARGON BUSTER

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

15 AUG

The Moon passes its first quarter phase and is visible 16° above the southwestern horizon

18 AUG

The kappa-Cygnid meteor shower reaches its peak of two meteors per hour

19 AUG

Asteroid 43 Ariadne is well placed for observation in Aquila, glowing at +9.6

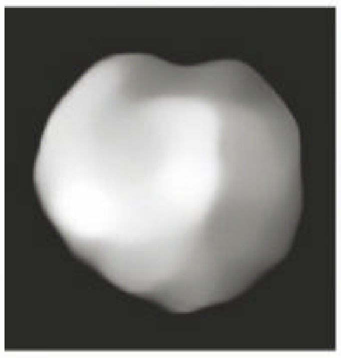
20 AUG

Uranus enters retrograde motion, glowing at magnitude +5.8 in Aries

24 AUG

Asteroid 89 Julia reaches opposition, glowing at magnitude +9.0 in Aquarius

Source: Wiki Commons © Astronomical Institute of the Charles University



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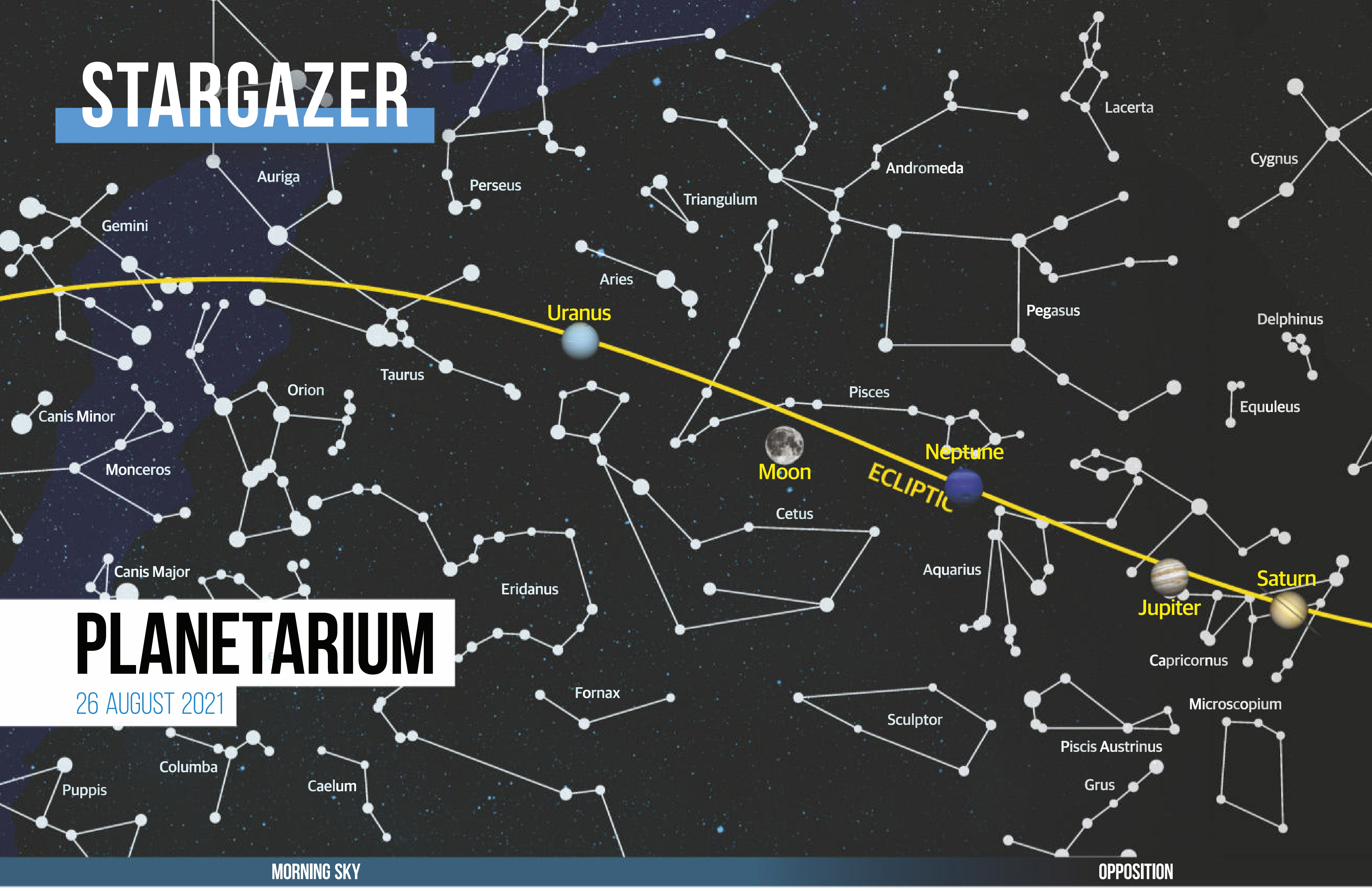
9 SEP

The epsilon-Perseid meteor shower reaches its peak of up to four meteors per hour

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

STARGAZER



PLANETARIUM

26 AUGUST 2021

MOON CALENDAR

* The Moon does not pass the meridian on 21 August

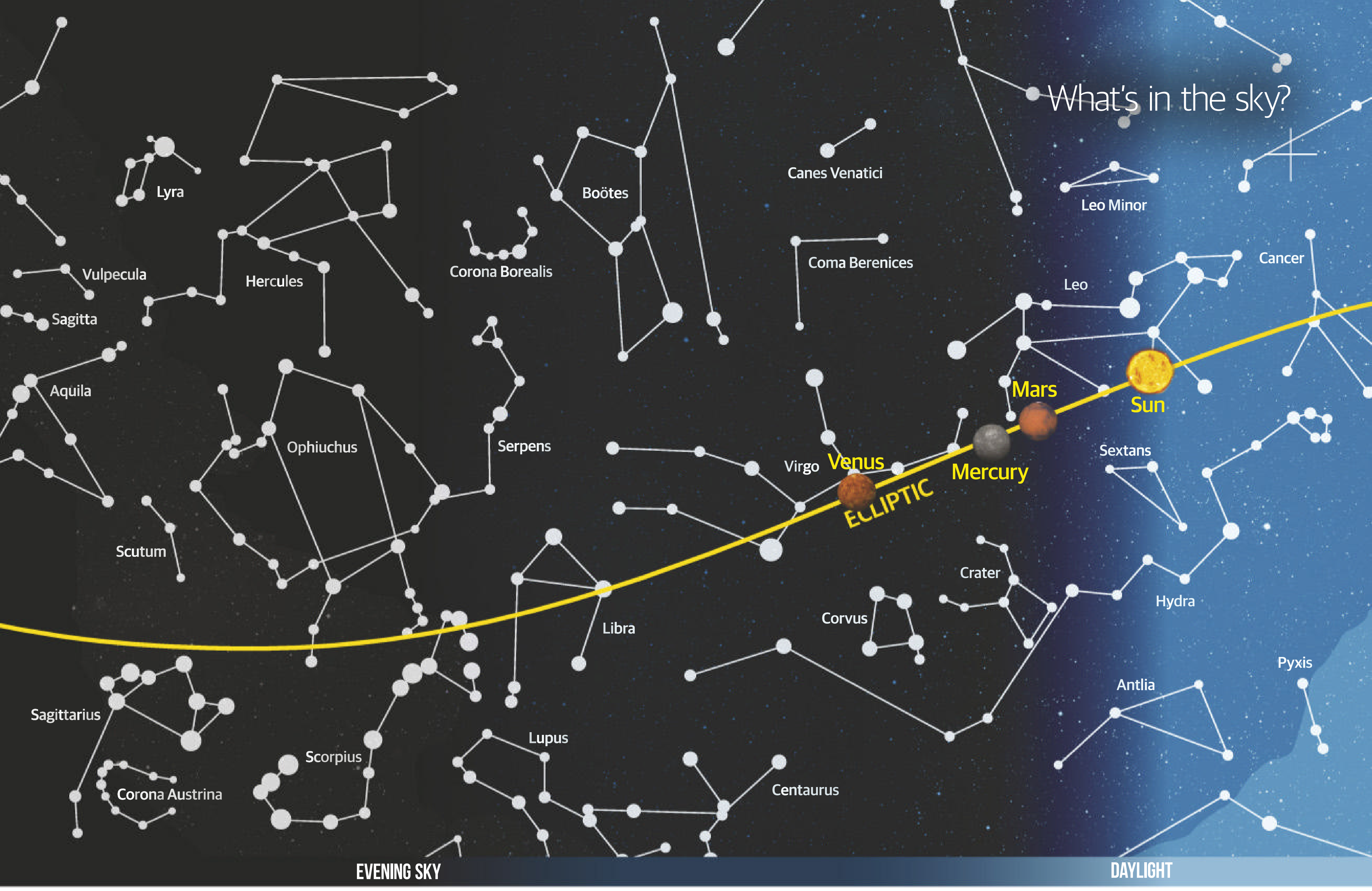
			12 AUG 18.6% ◓10:06 ◒22:23	13 AUG 28.5% ◓11:26 ◒22:39	14 AUG 39.6% ◓12:49 ◒22:58	15 AUG FQ 51.3% ◓14:13 ◒23:21
16 AUG 63.1% ◓15:38 ◒23:51	17 AUG 74.2% ◓16:59 ◒--:--	18 AUG 83.9% ◒00:32 ◓18:11	19 AUG 91.6%* ◒01:28 ◓19:08	20 AUG 96.9% ◒02:37 ◓19:50	21 AUG --:--%* ◒03:56 ◓20:21	22 AUG FM 99.5% ◒05:18 ◓20:44
23 AUG 99.5% ◒06:39 ◓21:02	24 AUG 97.0% ◒07:56 ◓21:17	25 AUG 92.4% ◒09:11 ◓21:31	26 AUG 86.1% ◒10:23 ◓21:45	27 AUG 78.4% ◒11:34 ◓22:00	28 AUG 69.7% ◒12:45 ◓22:17	29 AUG 60.4% ◒13:55 ◓22:38
30 AUG TQ 50.7% ◒15:04 ◓23:05	31 AUG 41.0% ◒16:09 ◓23:40	1 SEPT 31.5% ◒17:09 ◓--:--	2 SEPT 22.6% ◓00:26 ◒17:59	3 SEPT 14.6% ◓01:23 ◒18:39	4 SEPT 8.0% ◓02:31 ◒19:10	5 SEPT 3.2% ◓03:47 ◒19:35
6 SEPT 0.6% ◓05:06 ◒19:55	7 SEPT NM 0.5% ◓06:27 ◒20:12	8 SEPT 3.1% ◓07:49 ◒20:28	9 SEPT 8.4% ◓09:11 ◒20:45			

% Illumination
◓ Moonrise time
◒ Moonset time

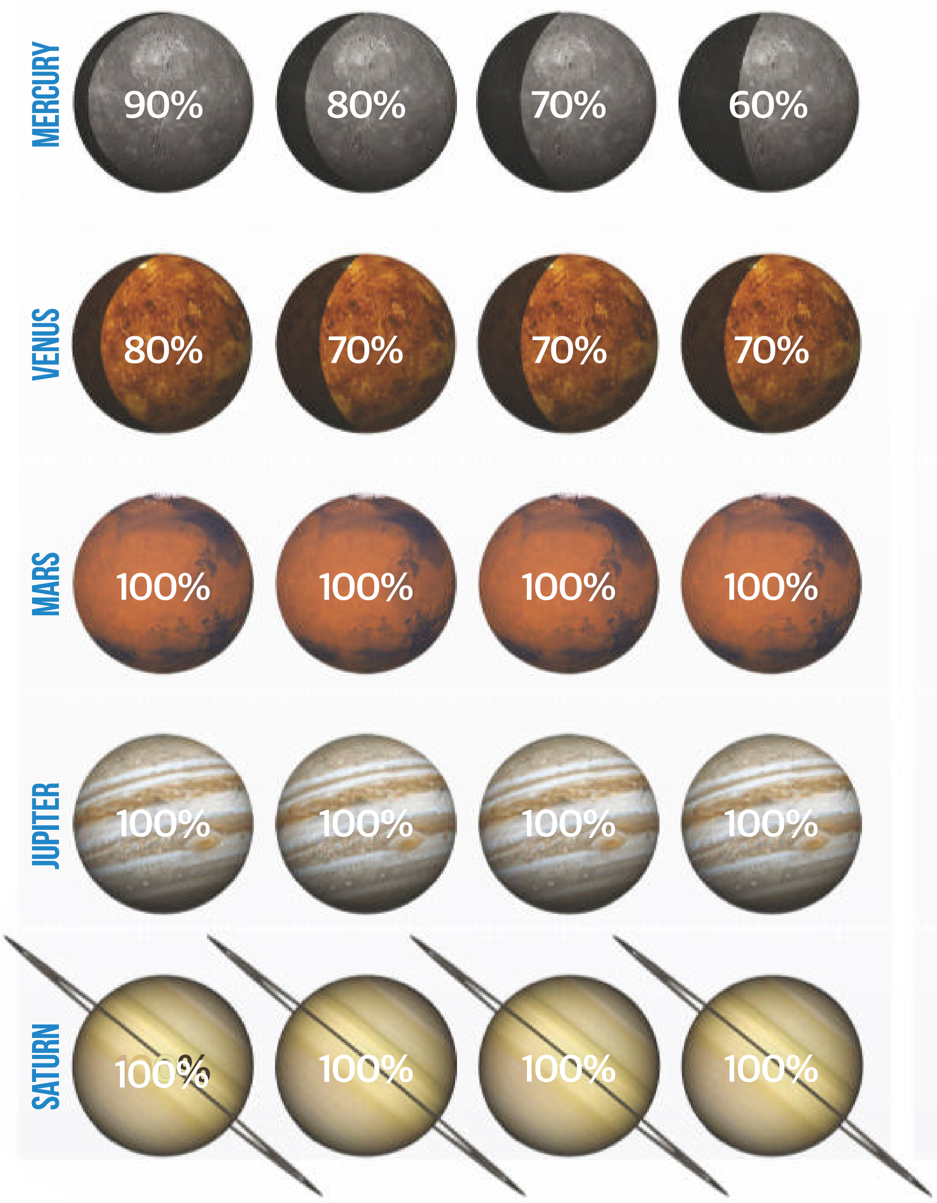
FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

* All figures are given for 00h at midnight (local times for London, UK)

What's in the sky?



ILLUMINATION PERCENTAGE



	19 AUG	26 AUG	2 SEPT	9 SEPT
MERCURY	90%	80%	70%	60%
VENUS	80%	70%	70%	70%
MARS	100%	100%	100%	100%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

PLANET POSITIONS

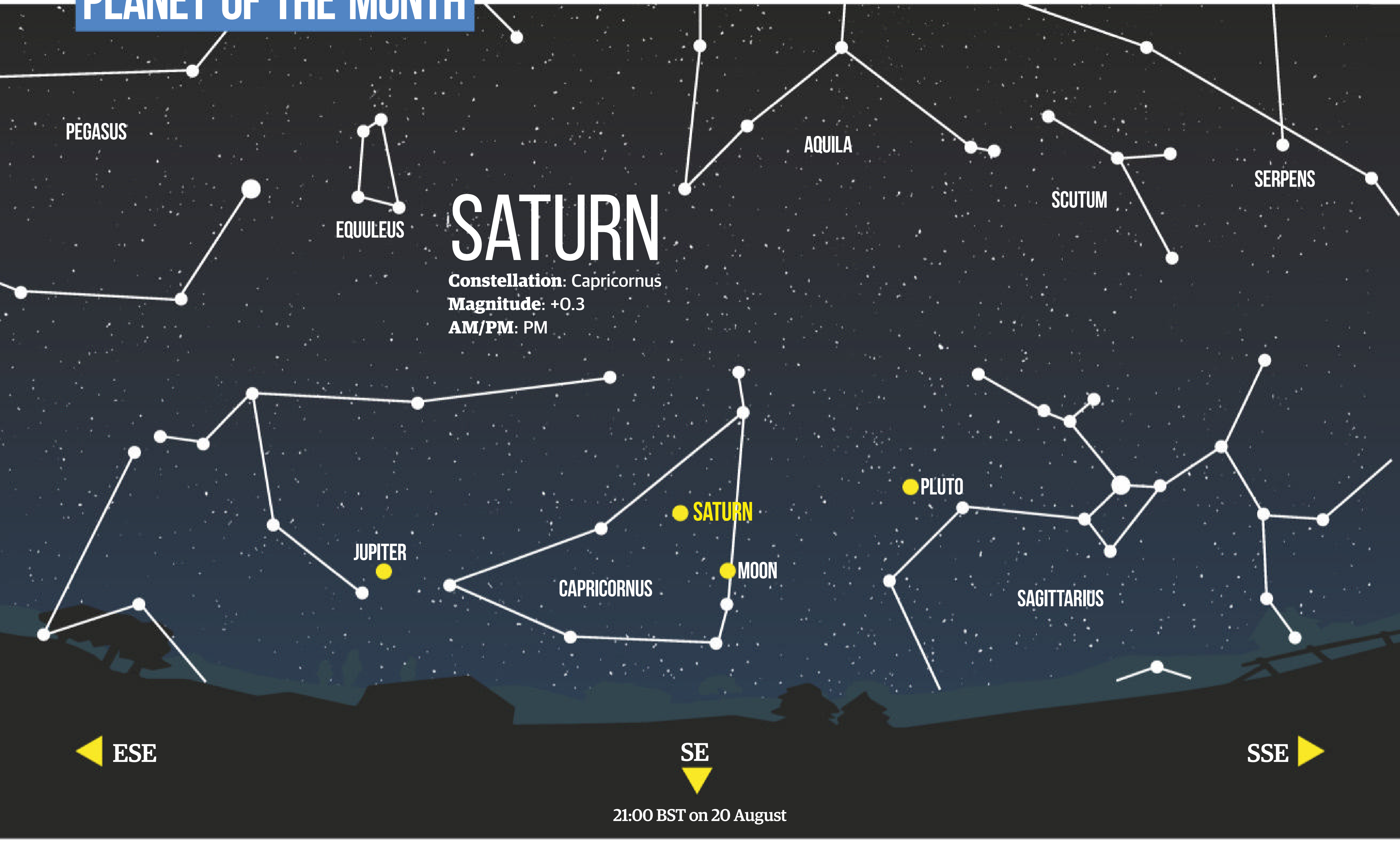
All rise and set times are given in BST

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
12 AUG	10h 10m 02s	+12° 57' 45"	Leo	-0.9	06:37	20:59
19 AUG	10h 56m 00s	+07° 49' 21"	Leo	-0.5	07:20	20:48
26 AUG	11h 36m 13s	+02° 39' 53"	Virgo	-0.2	07:59	20:34
2 SEPT	12h 11m 42s	-02° 14' 09"	Virgo	0.0	08:35	20:20
9 SEPT	12h 42m 39s	-06° 39' 08"	Virgo	0.0	08:59	20:00
12 AUG	11h 42m 08s	+02° 55' 18"	Virgo	-4.0	09:02	21:39
19 AUG	12h 12m 01s	+00° 40' 34"	Virgo	-4.0	09:23	21:15
26 AUG	12h 41m 41s	-04° 16' 42"	Virgo	-4.0	09:41	20:58
2 SEPT	13h 11m 23s	-07° 49' 21"	Virgo	-4.0	10:03	20:42
9 SEPT	13h 41m 18s	-11° 14' 52"	Virgo	-4.1	10:24	20:27
12 AUG	10h 40m 07s	+09° 31' 53"	Leo	+1.8	07:24	21:09
19 AUG	10h 56m 39s	+07° 48' 59"	Leo	+1.8	07:22	20:49
26 AUG	11h 13m 07s	+06° 03' 31"	Leo	+1.8	07:20	20:29
2 SEPT	11h 29m 34s	+04° 31' 26"	Leo	+1.8	07:18	20:09
9 SEPT	11h 46m 02s	+02° 26' 46"	Virgo	+1.8	07:16	19:48
12 AUG	22h 02m 16s	-13° 16' 18"	Aquarius	-2.9	20:45	06:29
19 AUG	21h 58m 45s	-13° 35' 58"	Capricornus	-2.9	20:16	05:56
26 AUG	21h 55m 13s	-13° 55' 19"	Capricornus	-2.9	19:46	05:24
2 SEPT	21h 51m 47s	-14° 13' 41"	Capricornus	-2.8	19:17	04:51
9 SEPT	21h 48m 34s	-14° 30' 27"	Capricornus	-2.8	18:48	04:19
12 AUG	20h 47m 17s	-18° 43' 27"	Capricornus	+0.2	20:04	04:50
19 AUG	20h 45m 16s	-18° 51' 45"	Capricornus	+0.2	19:33	04:18
26 AUG	20h 43m 22s	-18° 59' 26"	Capricornus	+0.3	19:02	03:45
2 SEPT	20h 41m 38s	-19° 06' 19"	Capricornus	+0.2	18:35	03:17
9 SEPT	20h 40m 06s	-19° 12' 17"	Capricornus	+0.4	18:04	02:45

THIS MONTH'S PLANETS

Track down the ringed giant in the evening sky throughout the warmer months - you'll be glad that you did

PLANET OF THE MONTH



SATURN

Constellation: Capricornus
Magnitude: +0.3
AM/PM: PM

21:00 BST on 20 August

Saturn is our Planet of the Month this issue, not because it's particularly bright or well-placed, but because it's in danger of being overlooked otherwise. The Ringed Planet will be visible in the southern part of the sky all through the long, light summer nights, but with much brighter and more obvious Jupiter as a close neighbour, Saturn risks being overshadowed. But even though it will be low in the sky this month, and less obvious than other planets, Saturn will still be an attractive target for summer stargazers.

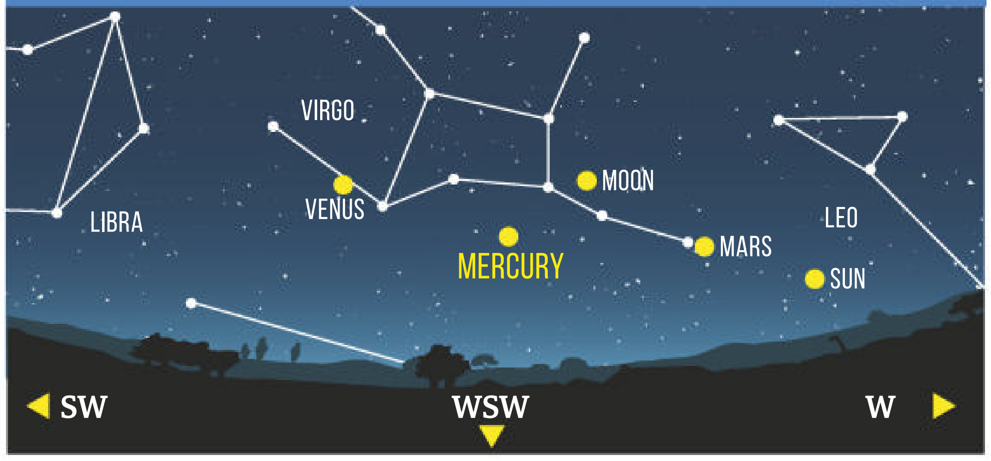
At the start of our observing period Saturn will be rising before the Sun has even set, so it will be visible all through the night. As it is carried slowly from east to west by the Earth's rotation the planet will remain low in the sky, tracing out a low arc across it.

At its highest it will only be 15 degrees or so above the horizon, which means you might struggle to see it if there are any hills, buildings or trees in that part of the sky at your observing site. But if you can see it, Saturn will look like a pale, golden-hued star less than 20 degrees to the right of much brighter, much bluer Jupiter.

Saturn is famous for its rings. Unfortunately they're not visible to the naked eye, and can't be seen through most binoculars, so if you want to see them you'll need a telescope. Made of countless chunks of ice, the rings have fascinated and entranced us ever since they were discovered more than four centuries ago by the first users of telescopes. Since then they have been photographed by larger and rather more sophisticated telescopes, both on the ground and in space, and by robotic space probes that have swept past or gone into orbit around the planet.

The photos these instruments have taken show breathtaking detail in Saturn's glittering hoops – thousands of rings packed together tightly. If you have a telescope of your own, you won't see that detail, but you will see the brightest, main rings. In fact, the brightness of the summer sky might help make the rings easier to see through your telescope because there will be less contrast between them and the sky.

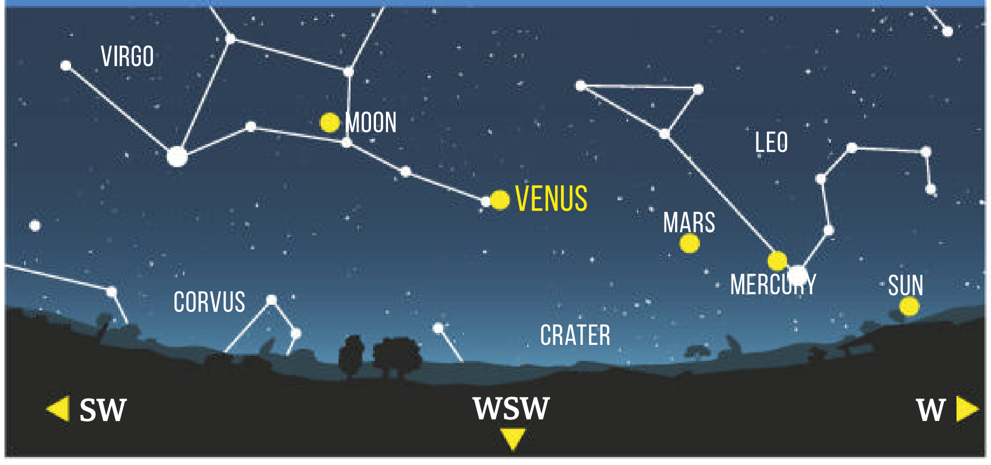
MERCURY 19:00 BST on 8 September



Constellation: Leo **Magnitude:** -0.9 **AM/PM:** PM

At the start of our observing period Mercury will be an evening object, visible down to the lower right of much brighter Venus. It should be visible to the naked eye - just - but you won't have long to observe the tiny heat-soaked world because it will be setting shortly after the Sun, shining very low in the western sky after sunset.

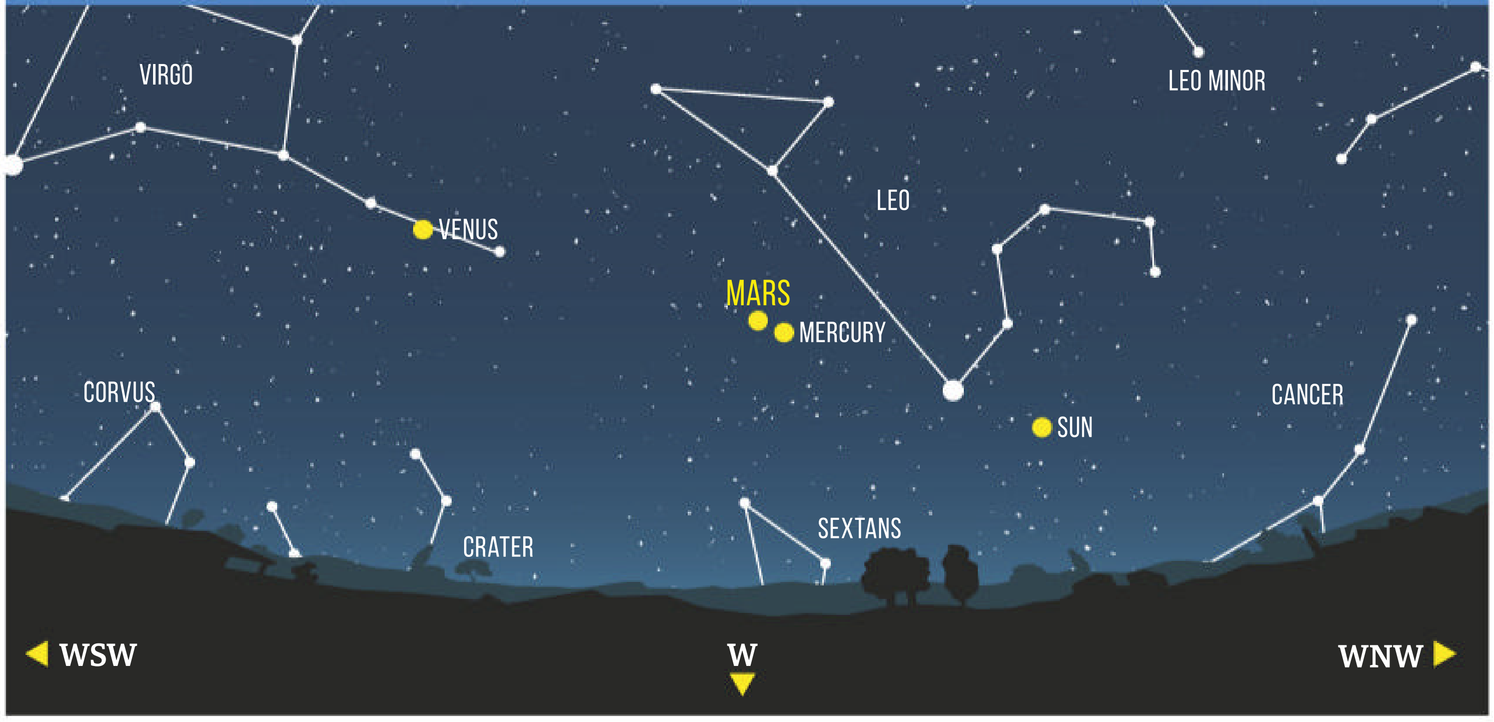
VENUS 20:00 BST on 12 August



Constellation: Virgo **Magnitude:** -4.0 **AM/PM:** PM

Venus, the second planet out from the Sun, is an easy-to-see 'evening star' during the coming month, a spark of light to the upper left of much fainter Mars, and Mercury too. At the start of the month, shining at magnitude -4.0, it will be visible to the naked eye even in the strong summer twilight, and won't set until 45 minutes after the Sun.

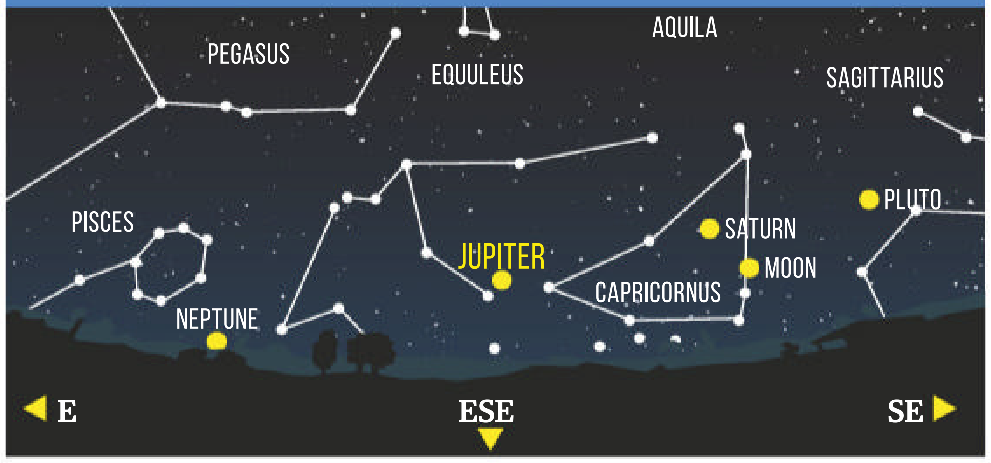
MARS 19:00 BST on 17 August



Constellation: Leo
Magnitude: +1.8
AM/PM: PM

Mars is an 'evening star' this month, but shining very low in the sky at magnitude +1.8 - barely brighter than the Pole Star - it will be drowned out by the summer evening twilight. You'll almost certainly need binoculars to see it, but you must only look for it after the Sun has set to protect your eyes. Between 17 and 19 August Mars will have a very close binocular encounter with Mercury, as the two planets appear to pass each other in the sky like jets. On 17 August Mars will be just under a degree and a half away from Mercury, shining to its upper left.

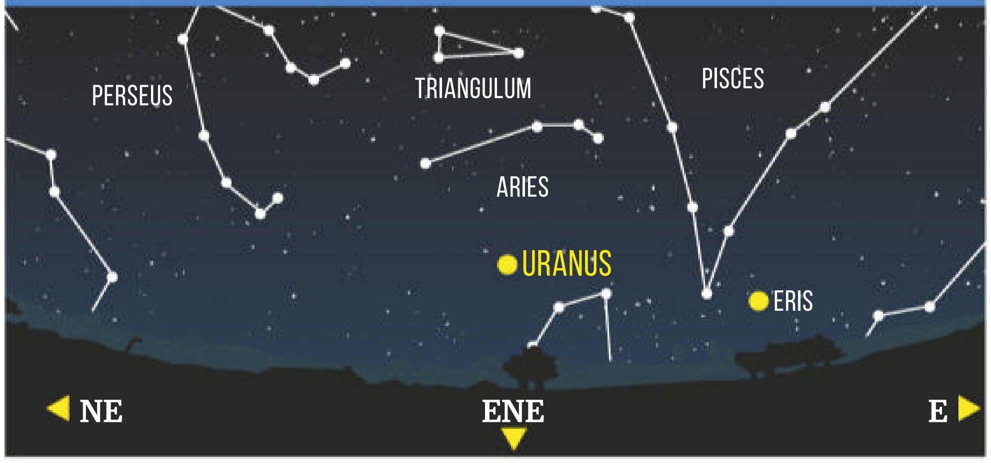
JUPITER 21:00 BST on 20 August



Constellation: Aquarius **Magnitude:** -2.9 **AM/PM:** PM

This month the largest planet in our Solar System will be visible from sunset until the sky begins to brighten with the approach of dawn. In mid-August Jupiter will be rising in the east at 21:00, just as the Sun is setting opposite it in the western sky, and by mid-September will be rising at 19:00 when the Sun is still blazing in the sky.

URANUS 22:00 BST on 11 September



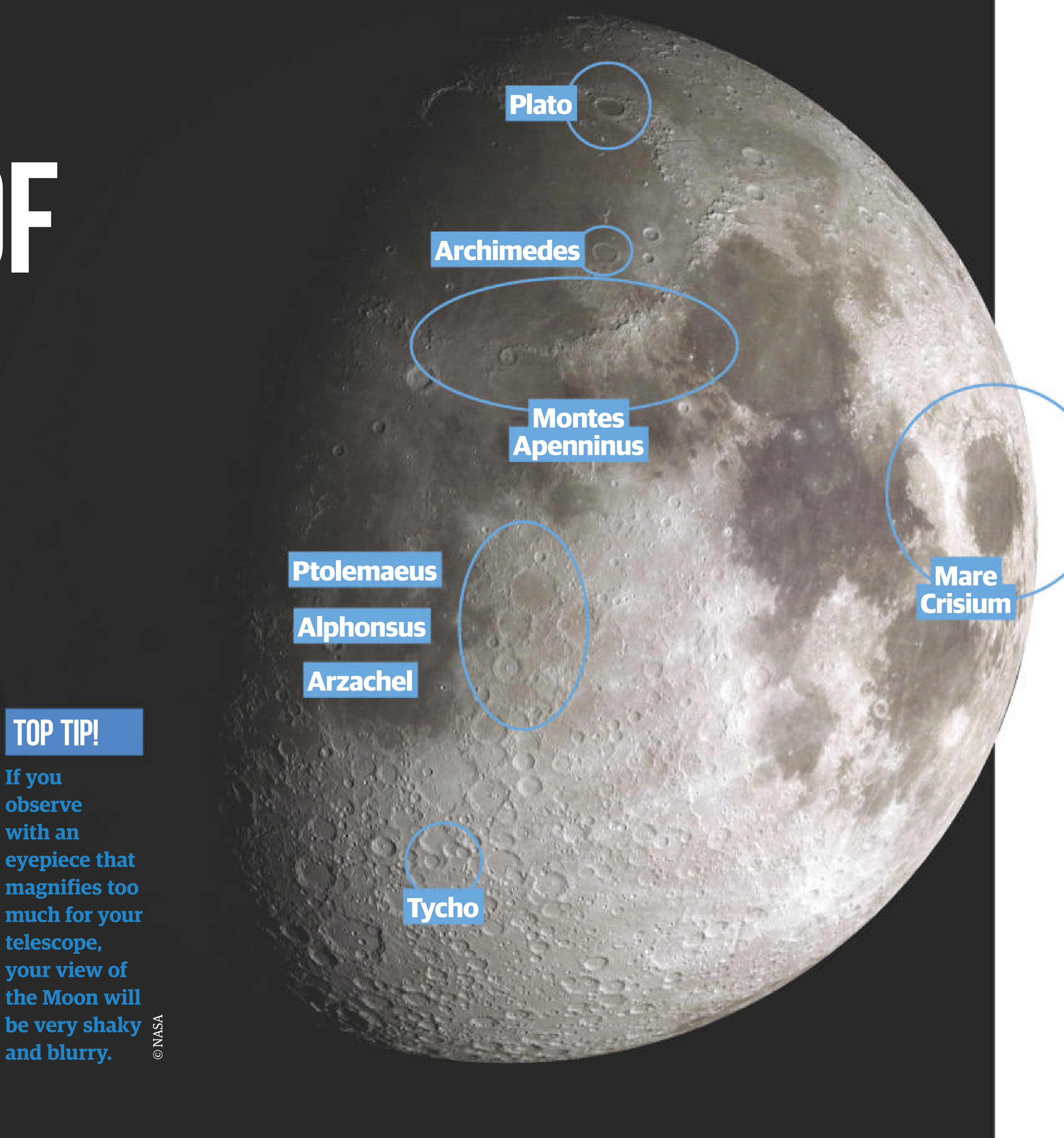
Constellation: Aries **Magnitude:** +5.8 **AM/PM:** PM

Uranus will be visible all through the night. At the start of our observing period it will rise at 23:00, but by mid-September it will be rising at 21:00. With a magnitude of +5.8 Uranus is visible to the naked eye during autumn and winter when the sky is dark, but during the summer months when twilight lingers all through the night it's a binocular or telescope object.

MOON TOUR

MAJOR CRATERS OF THE MOON

Take a tour of the Moon's most fascinating impacts



© NASA

TOP TIP!

If you observe with an eyepiece that magnifies too much for your telescope, your view of the Moon will be very shaky and blurry.

Each lunar phase offers different visual treats and delights. A crescent Moon - whether it's a very young new Moon hanging in the western sky after sunset or an old waning Moon glowing above the eastern horizon before sunrise - is a beautiful sight. It can look particularly striking if it happens to be shining close to a bright planet. And if the bright, sunlit crescent is quite thin you can often see the rest of the Earth-facing side of the Moon glowing with the subtle, lavender light of 'earthshine'.

Despite what many observers will tell you, the full Moon is not the worst phase to observe. True, with the Sun beating down mercilessly from high above there is no surface relief to see - no shadows are cast behind the Moon's jagged mountains or into its deep craters - but the full Moon is when it's easiest to see the contrast between the dark lunar seas and its rugged highlands, and to identify its major features, too. Full Moon is also the best time to see the bright 'rays' streaking across the Moon's face - trails of dusty debris sprayed out across the Moon by the impacts which blasted the youngest craters out of its surface.

However, one day of the lunar month offers the best of both worlds, and provides stunning views through binoculars and small telescopes. When the Moon is just slightly gibbous, a day past first quarter - what many people call a half Moon - it offers the observer fantastic views of every type of lunar feature. With the terminator - the line between lunar night and day - running almost straight down the middle of the Moon's face, the light is just perfect for seeing its craters, mountain ranges, sprawling seas and long debris rays.

Binocular views of the day-after-first-quarter Moon are fascinating, with the seas on the eastern side of the Moon's face clearly visible as dark blue-grey splodges and the largest craters along the terminator looking like pockmarks. Through a small telescope with a low-power eyepiece, with the day-after-first-quarter Moon almost filling the eyepiece you can easily imagine you're a space tourist flying towards the Moon in a spaceship.

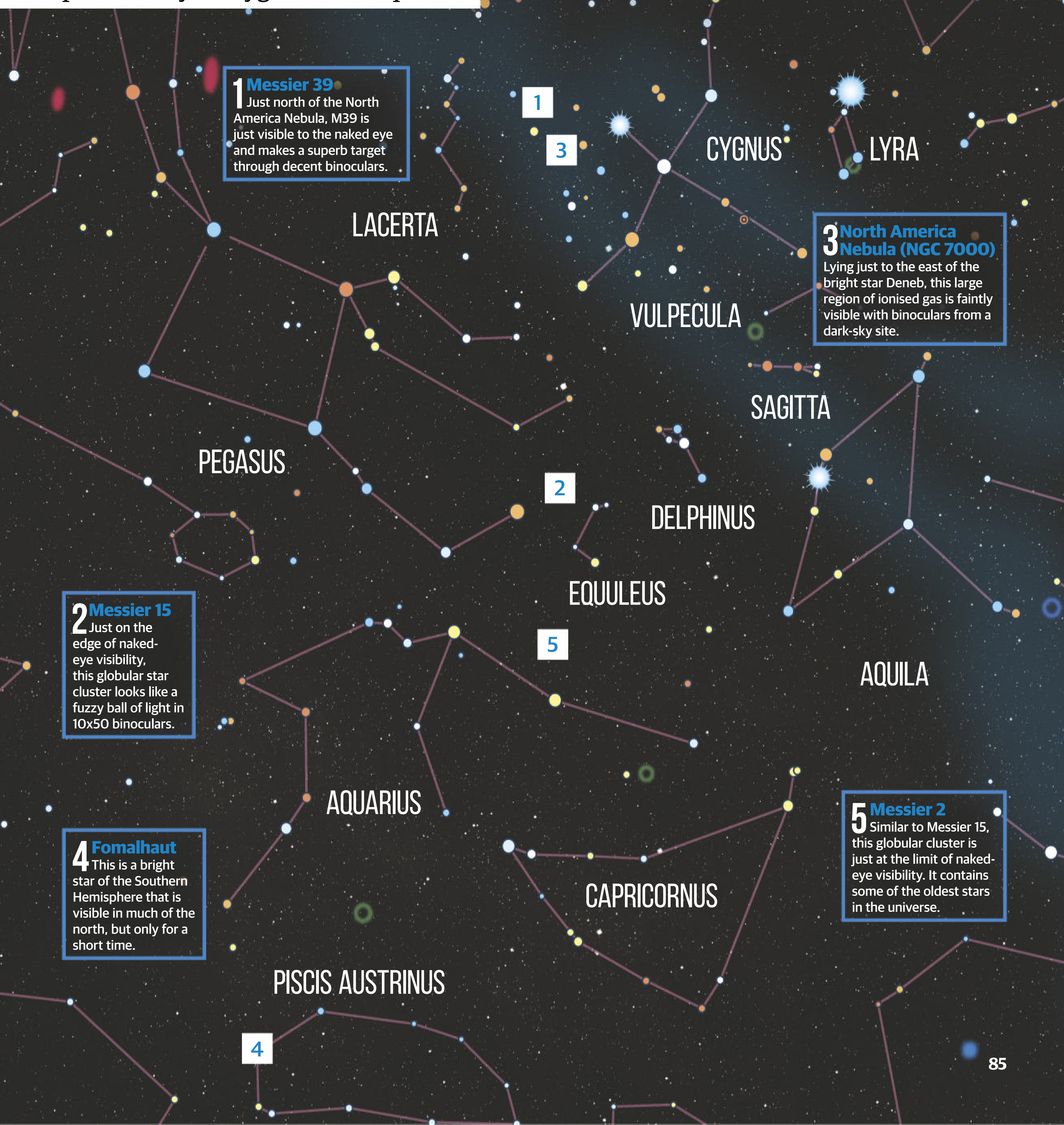
Increase the magnification so you're looking straight down into the craters along the terminator and you'll feel like you're standing behind the astronauts of the future as they descend towards the surface looking for a safe landing site, just as Armstrong and Aldrin did in 1969 as they guided the Eagle Lunar Module towards its historic landing in the Sea of Tranquillity.

The day after first quarter you will be able to see the sweeping curve of the jagged Montes Apenninus mountain range right on the terminator towards the north. Above those mountains, the crater Archimedes will stand out from the surface in stark relief, looking as fresh as if it had been carved out the day before. To the east, next to the curving limb, the oval sea Mare Crisium will look like a dark thumbprint on the Moon, and between it and the terminator other dark seas will form the shape of a crab's claw. In the centre, just to the right of the terminator, a chain of three craters, Ptolemaeus, Alphonsus and Arzachel, will look very impressive. At the top of the disc, on the terminator, the dark-floored crater Plato will stand out clearly, while back towards the bottom of the terminator the young crater Tycho will be starting to emerge from the shadows. As you stare down into it, Tycho might remind you of a bullet hole in a wall, or a pit left on the surface of a frozen lake after the impact of a heavy stone.

This observing period the Moon is at first quarter on the evenings of 15 August and 13 September, and if you observe it on those nights you will have fantastic views, but the following night those views will be just a little better. If you don't believe us, take a look yourself!

NAKED EYE & BINOCULAR TARGETS

Late summer nights are full of celestial wonders, particularly in Cygnus and Aquarius



1 Messier 39 Just north of the North America Nebula, M39 is just visible to the naked eye and makes a superb target through decent binoculars.

3 North America Nebula (NGC 7000) Lying just to the east of the bright star Deneb, this large region of ionised gas is faintly visible with binoculars from a dark-sky site.

2 Messier 15 Just on the edge of naked-eye visibility, this globular star cluster looks like a fuzzy ball of light in 10x50 binoculars.

4 Fomalhaut This is a bright star of the Southern Hemisphere that is visible in much of the north, but only for a short time.

5 Messier 2 Similar to Messier 15, this globular cluster is just at the limit of naked-eye visibility. It contains some of the oldest stars in the universe.

Andromeda Galaxy (Messier 31)

DEEP SKY CHALLENGE

THE GREAT SQUARE OF PEGASUS AND ANDROMEDA

The skies are getting darker now as we head towards the equinox, giving astronomers longer to enjoy the deep sky

During late August and September, the Great Square of Pegasus swings into view. Although the inside of the 'square' seems rather barren, it can be a good test of how clear your skies are – in other words, how much light pollution you suffer from. If you can see seven or more stars with the naked eye, you're doing quite well. The constellation of Pegasus is attached, as it were, to the neighbouring constellation of Andromeda, which is home to the famous spiral galaxy of the same name.

There's also another galaxy to see that's not too far away, but due to its low surface brightness, it's a much more challenging object. A nice open star cluster can be found in this region, too, which was discovered by Caroline Herschel – it's often overlooked, so make some time for it. There's a planetary nebula to seek out as well, known as the Blue Snowball, along with a couple of globular star clusters for you to pick out. All in all, it's a great region of the sky to visit with a telescope.

Triangulum Galaxy (Messier 33)

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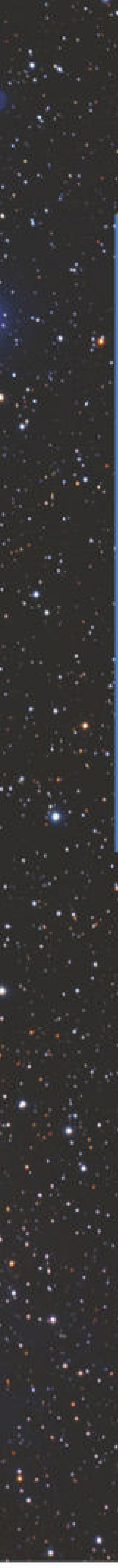


© NASA/ESA

1 **Messier 2**
Binoculars or a small telescope will show this globular cluster as a fuzzy 'star'. A larger telescope will start to resolve many of the individual stars in the cluster.

2 **Messier 15**
Slightly brighter than Messier 2, this globular star cluster is one of the oldest known clusters, and will look great in telescopes with an aperture of six inches or larger.

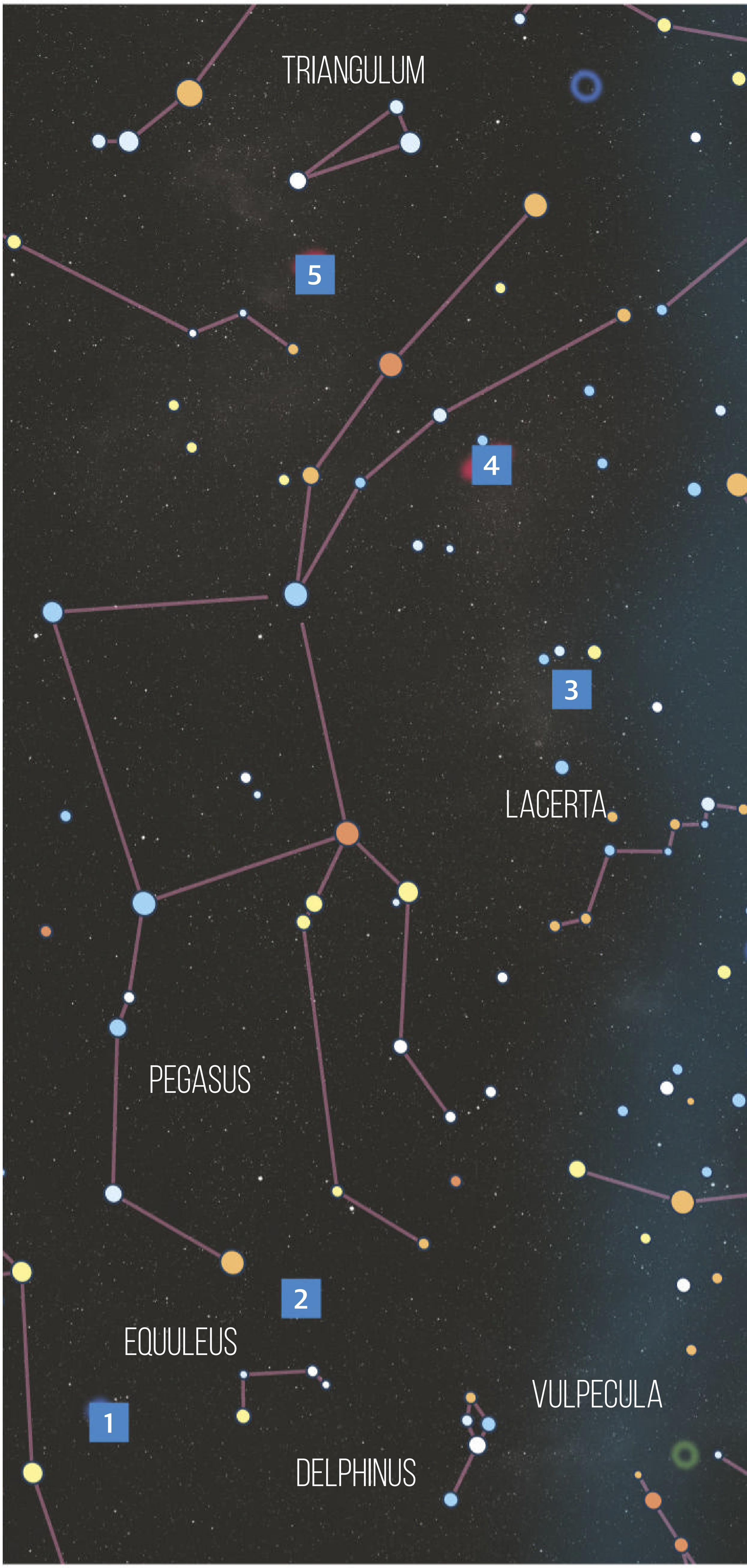
3 **The Blue Snowball**
This planetary nebula looks like a star with some nebulosity around it in a small telescope. A larger scope will show a slightly bluish disc.

4 **Great Andromeda Galaxy (Messier 31)**
The core of M31 is a fuzzy blob in a small telescope, while larger instruments will reveal its spiral structure. Messier 32 and NGC 205 are found nearby.

5 **The Triangulum Galaxy (Messier 33)**
A difficult object to spot in a small telescope due to it being faint and spread out, this lovely face-on spiral looks great in astrophotography images.

Source: Wikipedia Commons © Adam Evans

> "IT'S A GREAT REGION OF THE SKY TO VISIT WITH A TELESCOPE"



THE NORTHERN HEMISPHERE

Galaxies and globular star clusters are easy pickings for well-equipped astronomers in late summer

As we head into late summer, the night sky is alive with a selection of galaxies and star clusters. Starburst galaxy Messier 82, Messier 106 and neighbouring spiral Messier 94 all offer splendid views. If you're quick, naked-eye planets Saturn and Mars are also visible at dusk before setting within a few hours, while star clusters such as Messier 10, Messier 12 and Messier 14 are ideal for those who aren't looking to stay up too late.

For those keen to stay awake into the early hours of the morning, the galaxies of the constellations of Andromeda and Triangulum wheel into view, as well as a variety of open and globular star clusters, visible in a range of instruments.

USING THE SKY CHART

This chart is for use at 22:00 mid-month and is set for 52° latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.

MAGNITUDES

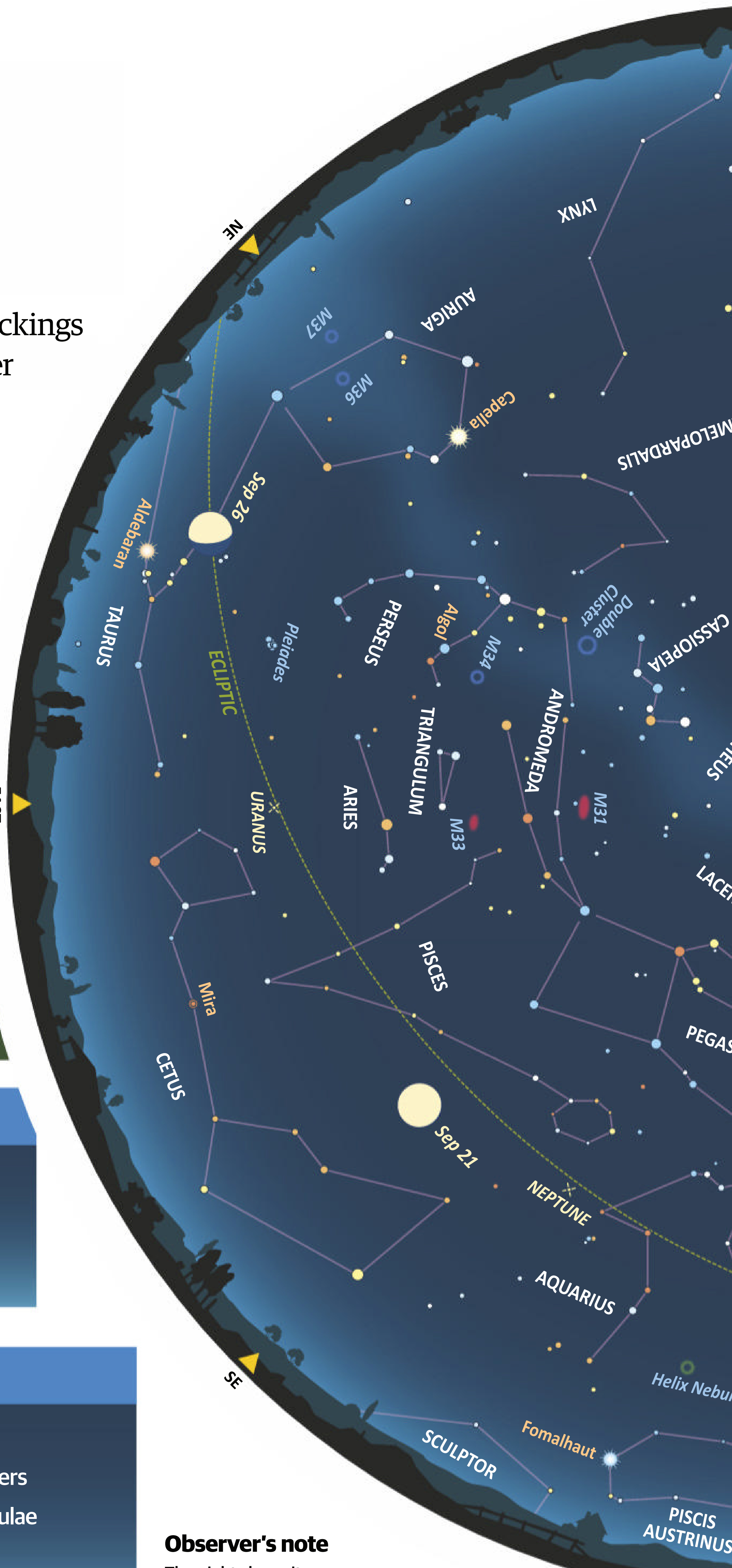
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

SPECTRAL TYPES

- O-B
- A
- F
- G
- K
- M

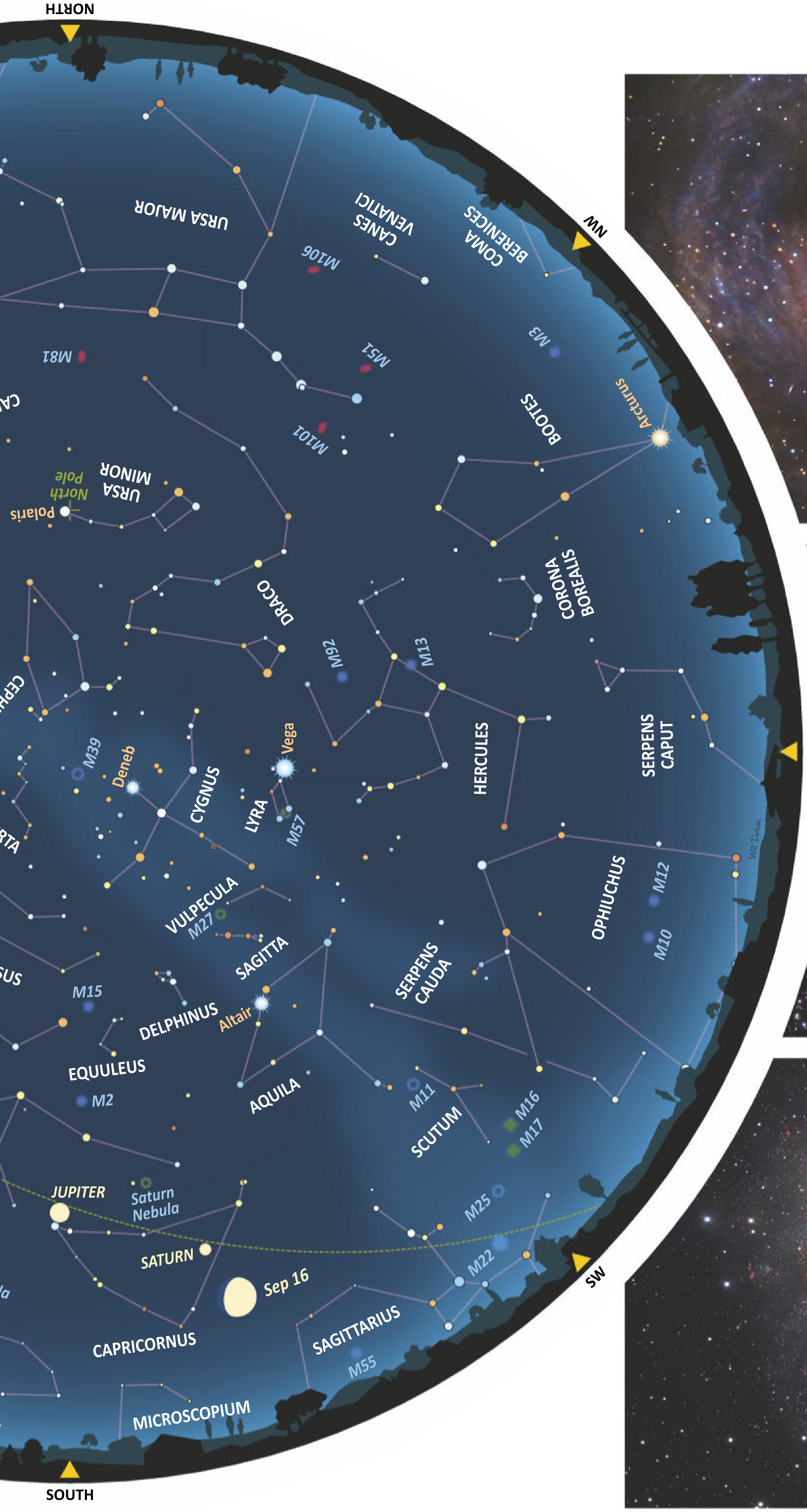
DEEP-SKY OBJECTS

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



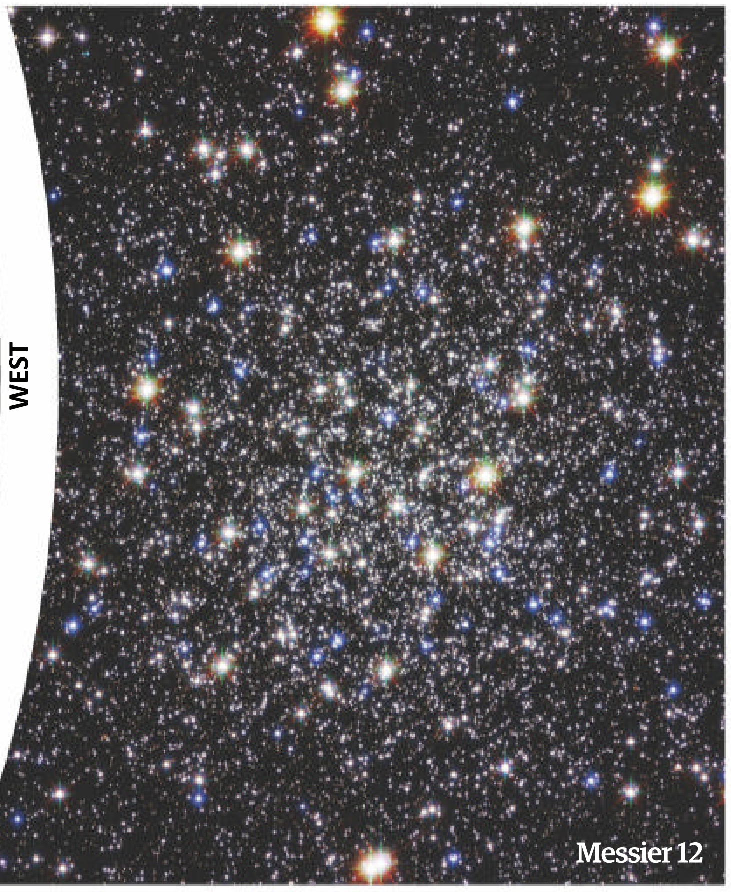
Observer's note

The night sky as it appears on 17 September 2021 at approximately 22:00 (BST)

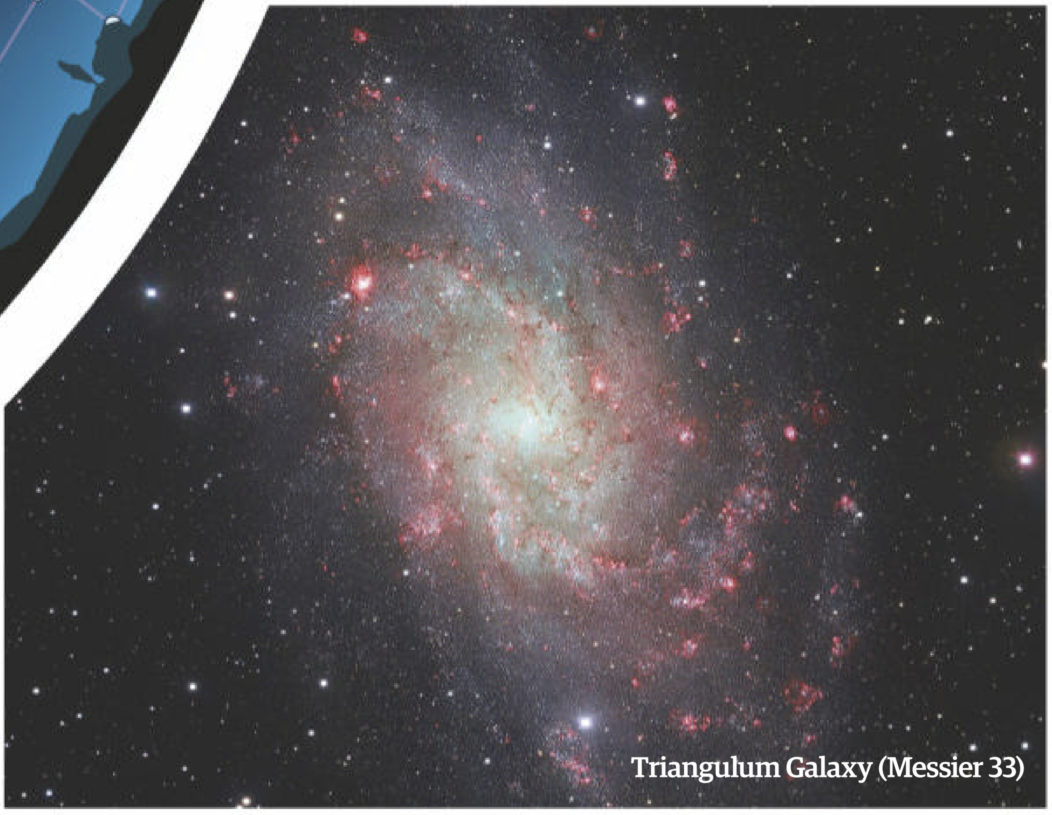


Messier 94

Source: Wikipedia commons © R Jay Gabany (Blackbird Obs.)


Messier 12

© ESA/Hubble & NASA


Triangulum Galaxy (Messier 33)

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ASTROSHOTS OF THE MONTH

Get featured in **All About Space** by sending your astrophotography images to **space@spaceanswers.com**

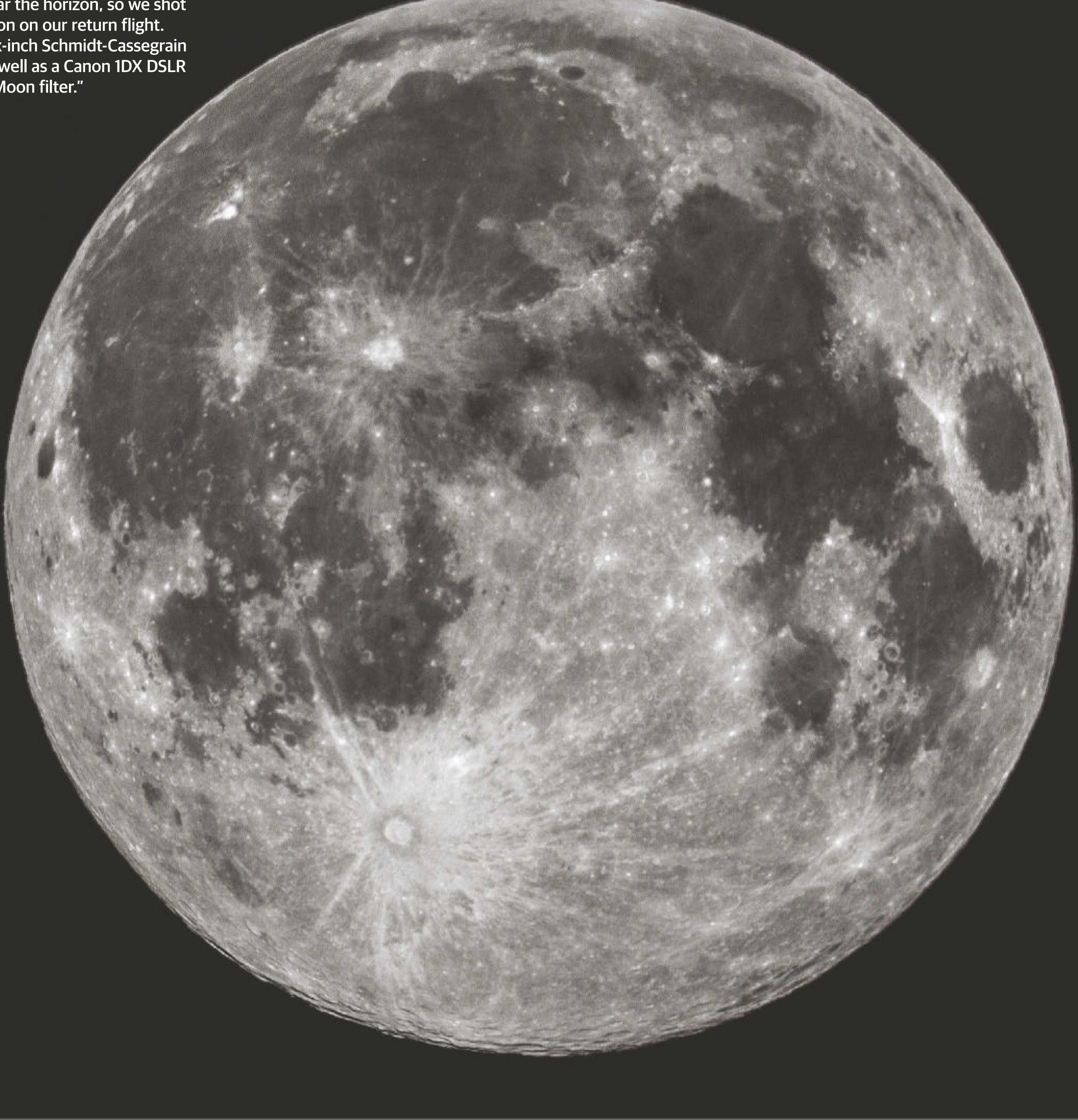
Denise Ametbay

Location: Republic of Kazakhstan, Central Asia

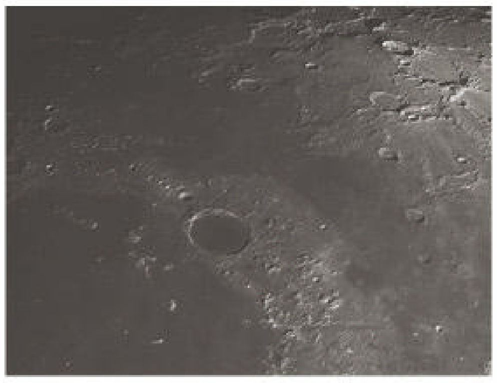
Telescope: Celestron SkyProdigy 6 Schmidt-Cassegrain

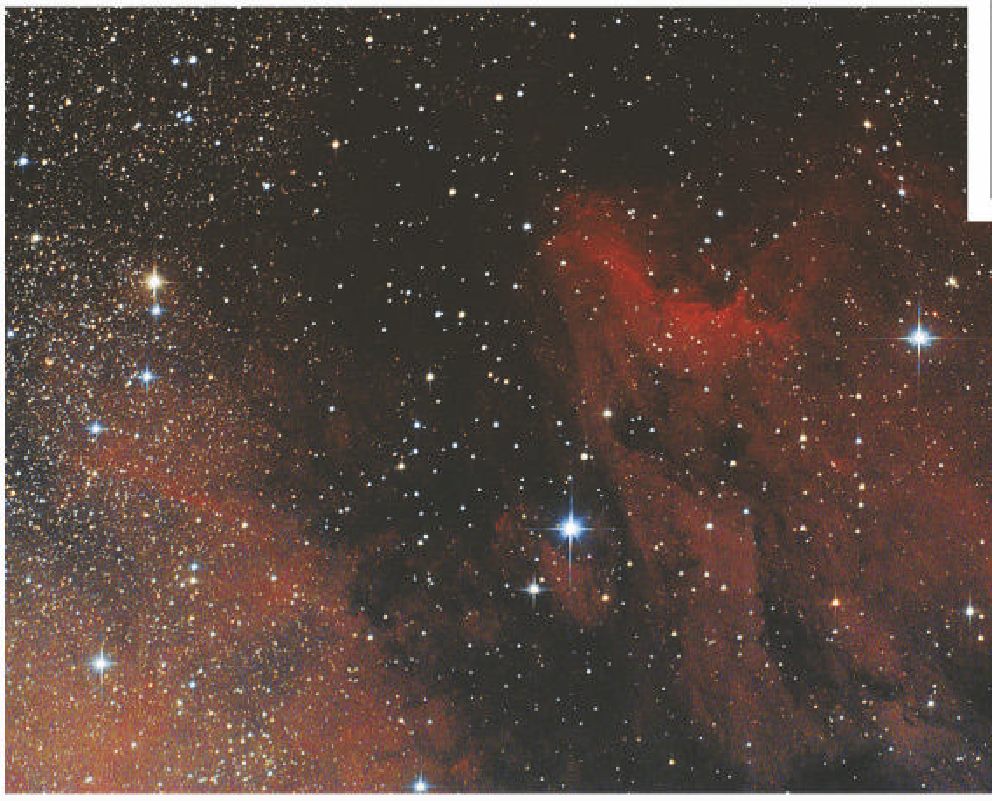
"I shot this image of the supermoon with my brother Omar when we were on vacation in Turkey. My hometown of Almaty is surrounded by mountains, so there was no possibility of capturing the Moon near the horizon, so we shot the supermoon on our return flight. We used a six-inch Schmidt-Cassegrain telescope as well as a Canon 1DX DSLR camera and Moon filter."

"I WANTED TO GET A BETTER RECORD OF MY OBSERVATIONS, WHICH LED TO AN INTEREST IN ASTROPHOTOGRAPHY"



Above: The Moon





Above: Plato, Vallis Alpes and Mare Frigoris

Left: The Pelican Nebula (IC 5070)

Below: Copernicus and Eratosthenes near Montes Apenninus

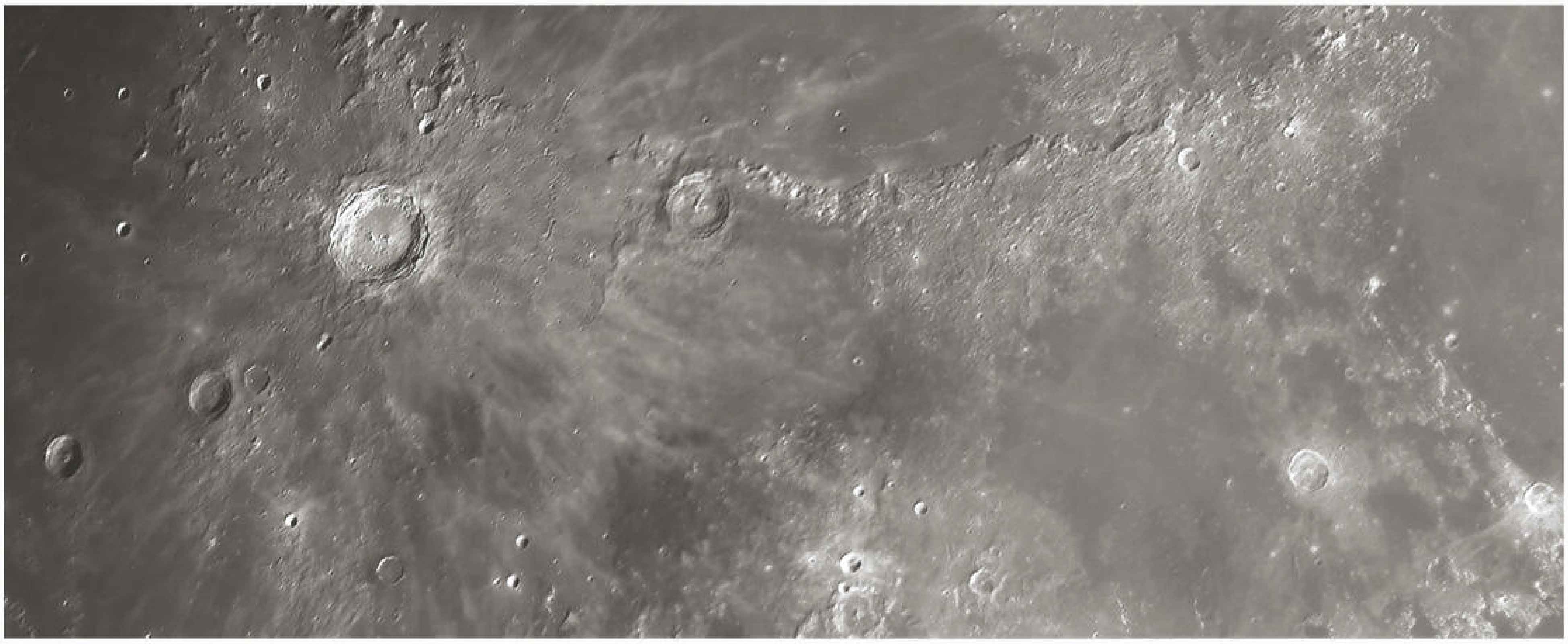
Alastair Woodward

Location: Derby, UK

Telescope: Sky-Watcher 130PDS

"When I initially began observing the night sky, in particular the Moon, I wanted to keep strictly to visual astronomy, but after six months of having the hobby, I wanted to get a better record of my observations, which led to an interest in astrophotography.

"My appreciation of dark skies was realised when I stayed in a small, inland village located in the south of France. The skies were the darkest I have ever seen, with stellar views of the Milky Way."



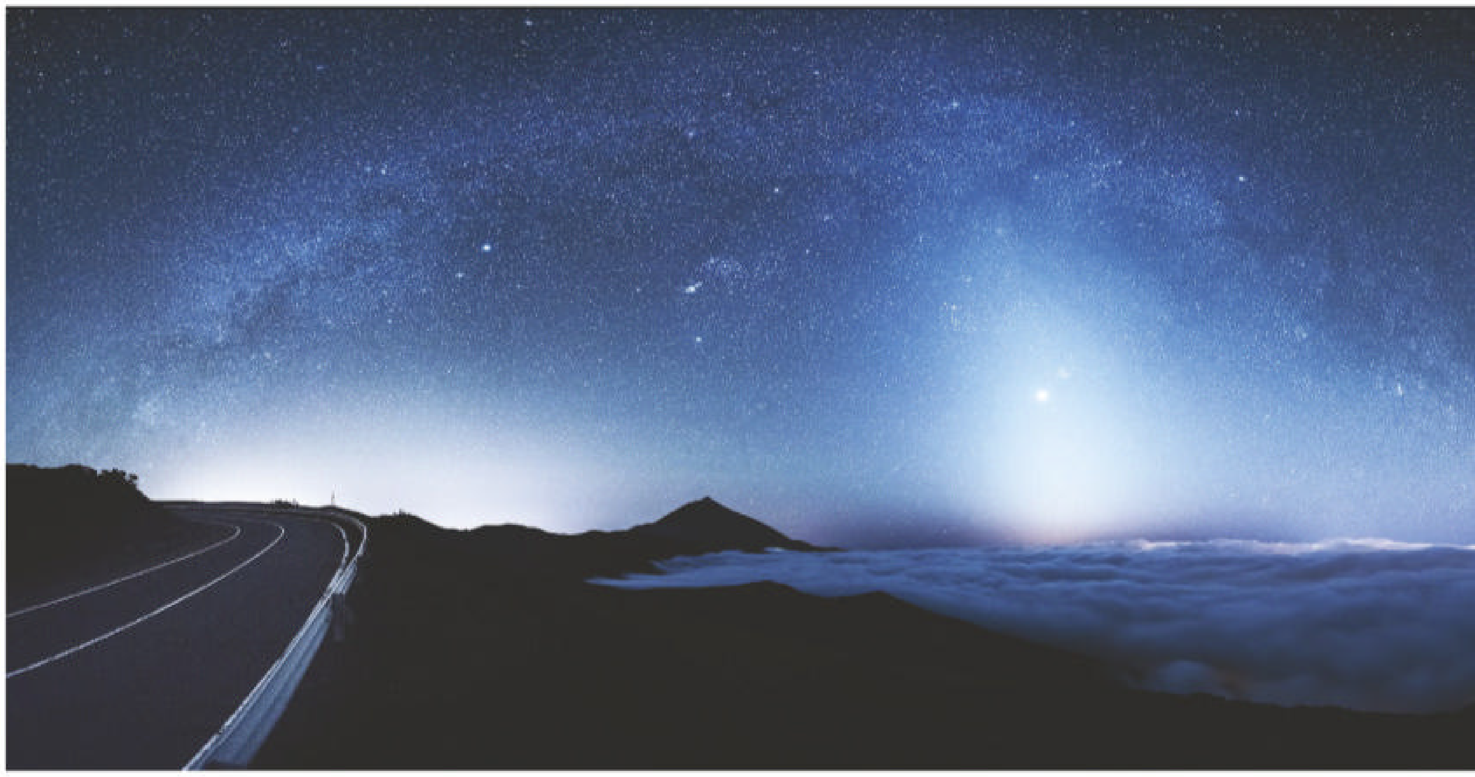
Ollie Taylor

Location: Portland, Dorset

Telescope: Sky-Watcher 130PDS

"I have been photographing landscapes with an emphasis on the night sky since winter 2011 after shooting aurorae in Iceland – something I had longed to do for years – and I have slowly developed my photographic style.

"In the right places, the location opens up to dark skies that appear to stretch out to eternity – perfect for stargazing. The use of apps to pinpoint the outer band of our galaxy allows me to align it with landscapes to generate nightscapes."



Right: Zodiacal light and the Milky Way over Mount Teide in Tenerife

REVIEW

NATIONAL PARK FOUNDATION FIRSTSCOPE

This spin on the Celestron FirstScope 76 offers great portability and provides fair night-sky views

Reviewed by Gemma Lavender

TELESCOPE ADVICE

Cost: £59.99 / $59.99
From: Amazon
Type: Newtonian reflector
Aperture: 2.99"
Focal length: 11.81"

BEST FOR...

- BEGINNERS
- SMALL BUDGETS
- PLANETARY VIEWING
- LUNAR VIEWING

The National Park Foundation FirstScope ticks all of the boxes on a novice sky-watcher's wish list when choosing their very first telescope: portability, ease of use and a price that's not going to break the bank. What's more, this tabletop telescope is supplied with all of the accessories you need for a fuss-free tour of the night sky, providing improved and more comfortable views of the planets and lunar surface compared to straining the unaided eye or arm fatigue brought about from supporting binoculars for long periods of time.

When unpacking the FirstScope, you'll notice that it is already preassembled, with only a finderscope needing to be affixed to the telescope tube. The Newtonian reflector is supplied with two eyepieces - 20mm and 4mm - and possesses a fast focal ratio to provide a wide field of view that's ideal for not only viewing the planets and the lunar surface, but also allows the observer to view diffuse, wide-angle targets such as star clusters.

Weighing in at a mere 1.95 kilograms, the FirstScope is ideal for those looking for a 'grab-and-go' instrument. On close inspection of the overall build, we discovered that the finish isn't perfect, with traces of glue apparent on the tube. However, considering what you get for the price, we did note that the telescope's plastics are not glossy and cheap compared to other instruments that fall in a similar price range. You'll notice that the telescope's base is short, meaning that you'll need to place it on a table in order to use it comfortably. This may be a hindrance for some observers, but if you have children who have been pestering you for a telescope, the FirstScope is the perfect solution, especially given its small build and ease of use.

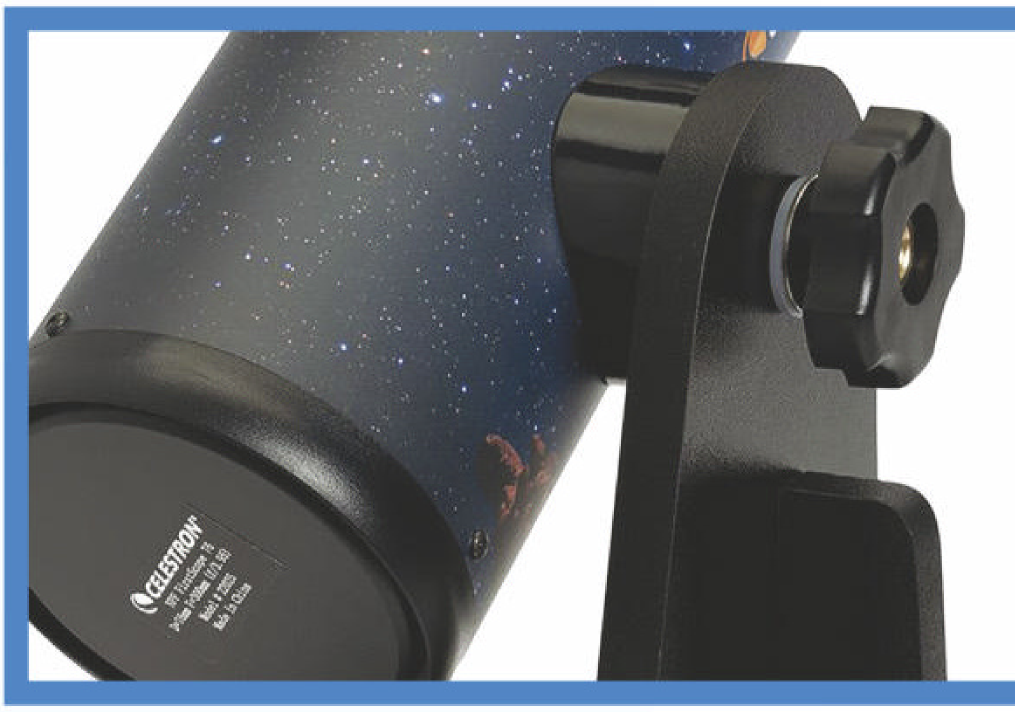
With Newtonian designs, the two mirrors within the tube should be aligned. Astronomers usually achieve this process - known as collimation - using thumbscrews to adjust the optical system. Unfortunately, these aids are only usually on the more expensive models, meaning it was quite a task trying to collimate the FirstScope - the primary mirror isn't adjustable and a collimation cap or eyepiece isn't included with the telescope.

Navigation will be tricky, too, since a finderscope isn't supplied either. Despite the shortcomings, however, we couldn't wait to see what the FirstScope was capable of - especially given that we could get started in astronomy with a quick slew of the telescope tube.

A clear sky offered a gaggle of Solar System targets, including Jupiter, Venus, Saturn and the Moon, for us to test out the telescope's optical system. Our lunar companion was at 22 per cent illumination, meaning that there wasn't too much

Main: The special design of the tube is very attractive - much better than the standard greys and blues

Left: This scope is perfectly portable due to its small size



Above: With no finderscope included, hunting down targets is challenging

> “IF YOU HAVE CHILDREN WHO HAVE BEEN PESTERING YOU FOR A TELESCOPE, THE FIRSTSCOPE IS THE PERFECT SOLUTION”

natural light pollution to hinder our view of other targets.

With the eyepieces supplied by Celestron, you won’t get hugely close-up views of the surface of the Moon, but you’ll be able to see craters and get a feel for the rugged terrain along the terminator – the point where night meets day. The optics don’t provide pin-sharp sights through the field of view since the focuser tube is quite loose, but even such basic observations are sure to delight those who have always wanted to get a closer look at the lunar surface without straining their eyes.

The second planet from the Sun, Venus, made for an easy target in the southwest, shining at a stunning magnitude of -4.9. Visible as a bright-white ‘star’ to the unaided eye, we hoped for good views through the FirstScope, but as suspected we didn’t see a great deal of detail, with glare making it difficult to distinguish a phase. Saturn was small, faint and fuzzy in the field of view, yet it was possible to make out the gas giant's rings and yellow colouration.

The FirstScope's wide-angle views did manage to provide fair sights of the Pleiades (Messier 45) in the constellation of Taurus. Each of the young, hot member stars in this open cluster sat neatly and clearly in the field of view with some minor adjustments of the focuser.

Navigating without a finderscope did prove quite cumbersome during our observations, making star-hopping especially difficult. The FirstScope needs to be equipped with a light finderscope, but given that the least overbearing optical finderscopes fail to pick up stars with magnitudes below naked-eye visibility, we recommend using a red-dot finder, especially in light-polluted areas.

Waiting until dawn was worthwhile as Jupiter, which shone at magnitude -1.9, rose in the southeast. While it was difficult to spot any details on the gas giant, such as its belts and Great Red Spot, without the use of a filter, the Galilean moons – Io, Ganymede, Europa and Callisto – appeared as bright points of light either side of its equator. While the FirstScope's offerings aren't as impressive as those achieved through a dedicated telescope, they are sure to provide a 'wow factor' for first-time and younger observers.

The FirstScope promotes fuss-free observing, but provides views that will disappoint astronomers looking for an additional piece of kit to supplement their hobby. Better suited as a beginner telescope, this Newtonian reflector is a worthwhile low-budget purchase for children – especially if you suspect that astronomy is likely to be a passing phase or if basic but fair views of the Moon, planets and stars are suitable before investing in an upgrade.

For the price, the FirstScope is supplied with a basic build that's suitable to begin casual tours of the night sky. However, if you're looking to make the most of its optical system while improving navigation, we recommend getting a red-dot finder, investing in a set of eyepieces that are respectful of the telescope's highest useful magnification of 180x and filters that will improve the contrast of Solar System targets.

FOR

- ⊕ Portable
- ⊕ Easy to use
- ⊕ Robust build
- ⊕ Low investment for casual or young astronomers
- ⊕ Fast focal ratio for easy observations of wide-angle targets

AGAINST

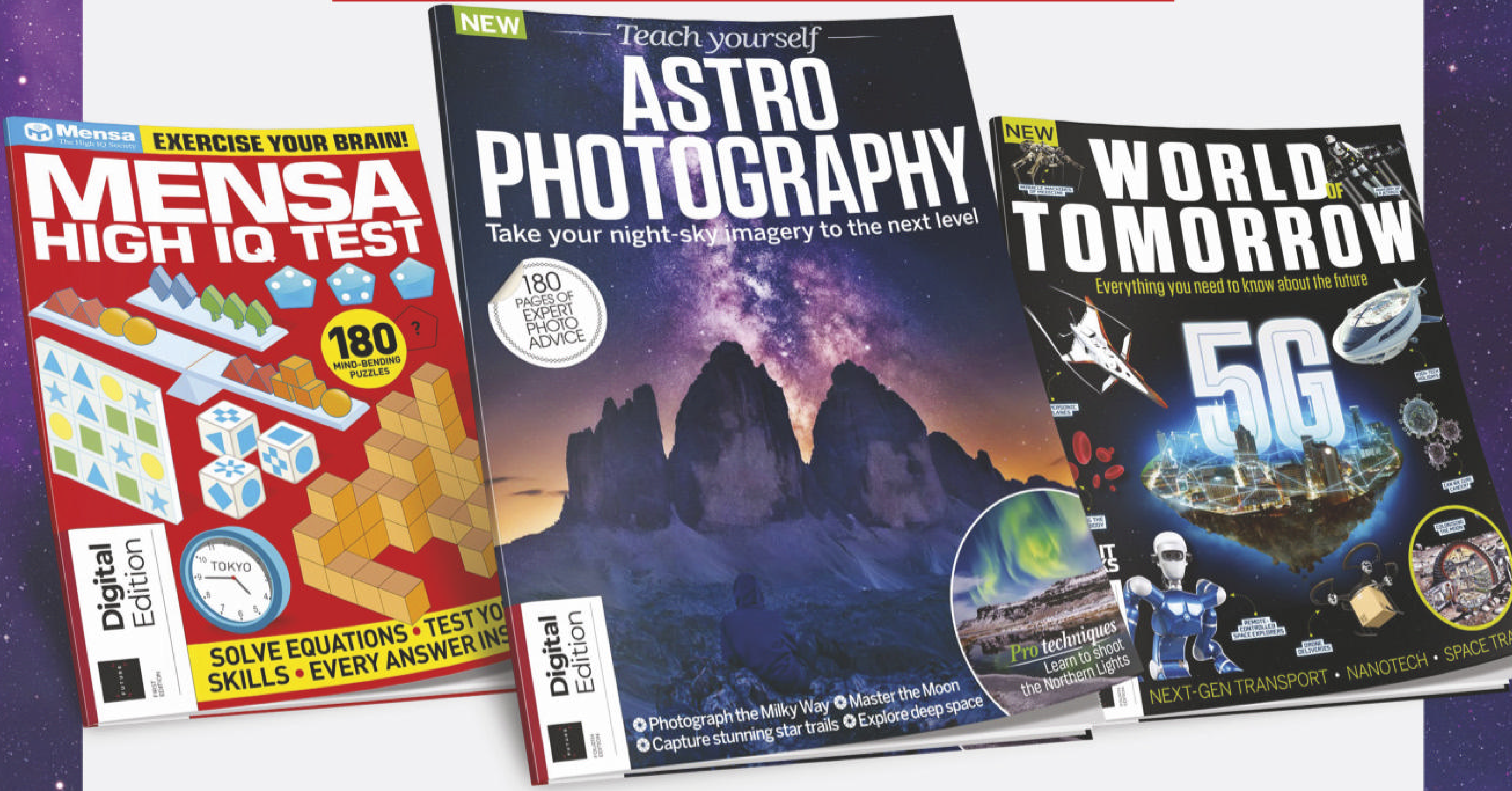
- ⊖ Loose focuser
- ⊖ Some observations lack clarity and detail
- ⊖ A challenge to collimate
- ⊖ Finderscope not supplied

> "SATURN WAS SMALL, FAINT AND FUZZY IN THE FIELD OF VIEW, YET IT WAS POSSIBLE TO MAKE OUT THE GAS GIANT'S RINGS"

Right: The two supplied eyepieces are comfortable to use, and more can be bought for the scope

3 FREE DIGITAL BOOKS

FOR EVERY READER!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TEACH YOURSELF ASTROPHOTOGRAPHY

Astrophotography can seem very daunting at first, but it's one of the most rewarding hobbies once you learn the basics. The photographic possibilities that the night sky offers are incredibly vast, from landscape shots with the Milky Way behind them to photographing far-away planets and galaxies. Explore the differences between galaxies and nebulae, find out when to shoot the Moon and learn how to capture aurorae. Inside we've included jam-packed features, in-depth tutorials, interviews with professionals and creative projects. Whether you're a novice or seasoned space expert, **Teach Yourself Astrophotography** has something for you.

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IN THE SHOPS

The latest books, apps, software, tech and accessories for space and astronomy fans alike

FOR FUN

NASA MOON MINER GAME

Cost: £9.99 (approx. $13.75)

From: thumbsup.com

1 Do you think you have what it takes to mine the surface of the Moon while keeping your astronaut safe and making sure your opponents don't receive a bigger haul of the lunar bounty than you? If so, this suspense strategy game is for you. The integrity of the lunar surface is compromised with every lunar rock you mine. Will you choose to play it safe and go for the non-integral pieces, or be a mining maverick and go for the structurally important pieces and hope that it's your opponent that suffers the consequences of your risky behaviour? The game is suitable for two to four players ages five and up.

FOR OBSERVING

SKY-WATCHER 9x50 RIGHT-ANGLED ERECTING FINDERSCOPE

Cost: £75 (approx. $103.10)

From: firstlightoptics.com

2 This is the finderscope your neck and back have been looking for. The practical design not only permits a more comfortable viewing experience, but also provides an upright image with corrected left-right image orientation. The 50mm aperture results in a good light-gathering capacity, with a 45-degree field of view and crosshair reticle for aiding navigation. The quick-release finder-mounting bracket fits most standard finder shoes from brands such as Celestron, Sky-Watcher and Vixen.

FOR SCHOOL, UNIVERSITY OR THE OFFICE

SPACE AGE PENCIL CASE

Cost: £7.75 (approx. $11)

From: rexlondon.com

3 Keep your pens and pencils organised in this retro space age pencil case. Whether you need to keep your stationary safe for a trip to the Moon and back or are simply heading to school or the office, this case won't let you down. It not only looks great, but is practical too, as the oilcloth design can be easily wiped down. Matching accessories such as coloured pencils and erasers are also available for a complete cosmic set. The pencil case is approximately 21 centimetres (8.2 inches) long, nine centimetres (3.5 inches) tall and six centimetres (2.3 inches) wide.

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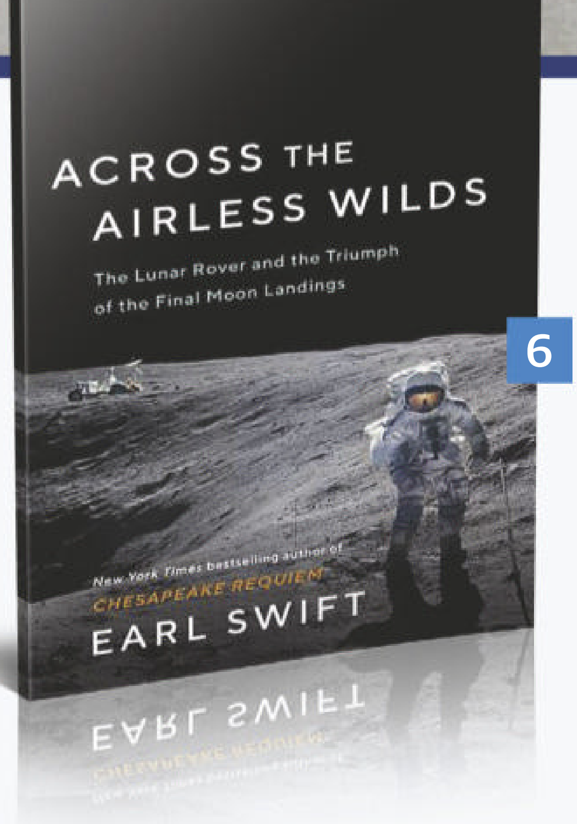
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6

FOR YOUR HOME

SET OF FOUR MOON PHASE MARBLE COASTERS

Cost: £29.50 (approx. $40.50)

From: oliverbonas.com

4 These charming marble coasters, embellished with a decorative, golden Moon phase design, are the perfect accessory to elevate your tableware. Each coaster features a different Moon phase in a brushed-brass finish that delicately compliments the marble base. The lunar coasters are ten centimetres (3.9 inches) wide and five centimetres (1.9 inches) tall. Due to the marble and brass nature of these coasters, they should be wiped clean with a damp cloth and are not suitable for the dishwasher.

FOR SPECIAL OCCASIONS

OVAL METEORITE CUFFLINKS

Cost: £225 (approx. $309.50)

From: marthajackson.co.uk

5 Who wouldn't want to own their own slice of a Muonionalusta meteorite that fell to Earth over a million years ago? These elegant cufflinks contain a valuable piece of natural history that has been preserved and transported in glaciers, only to be found years later in a remote region of northern Sweden. The iron-nickel meteorites are not only rare, but are also almost always buried in permafrost. Under Swedish law, a license must be obtained to allow for the excavation of the material, which also needs to be carried out by hand. These are some seriously stunning cufflinks, with a fascinating backstory to boot.

FOR BOOKWORMS

ACROSS THE AIRLESS WILDS

Cost: £22 / $28.99

From: Waterstones / amazon.com

6 From *New York Times* bestselling author Earl Swift is a remarkable tale of how the final three Apollo missions - Apollo 15, 16 and 17 - were the pinnacle of human exploration. Swift explores the engineering marvel of the Lunar Roving Vehicle, detailing how the buggy enabled extensive lunar exploration and discoveries. The informative and fascinating narrative shines a spotlight on these often-overlooked yet crucial missions and introduces you to some of the captivating characters who helped to make it all possible. *Across the Airless Wilds* is a true celebration of human brilliance and technological advancement.

HEROES OF SPACE

DR CAROLYN SHOEMAKER

A trailblazing and highly observant astronomer, Shoemaker was the ultimate comet hunter

Carolyn and her husband recieved the Rittenhouse Medal

© Getty

Shoemaker was a truly remarkable astronomer, having discovered over 800 asteroids and at least 32 comets. What makes Shoemaker's achievements even more extraordinary is that they were accomplished by a woman who took up astronomy in 1980, at the age of 51.

Shoemaker was born in 1929 in Gallup, New Mexico, and her family then moved to California. But the would-be world-renowned astronomer didn't show any interest in astronomy at school. Instead she decided to study history and political science at Chico State University, now known as California State University, Chico.

After college, Shoemaker found herself working as a teacher, a career choice she wasn't too enthused about. Then, at her brother's wedding, she met geologist Gene Shoemaker, who was her brother's roommate at the California Institute of Technology (Caltech). This chance encounter would be the start of a long and fruitful relationship, and the beginning of Carolyn's path into astronomy. The Shoemakers married and built a house in Flagstaff, Arizona, where they raised three children, and Gene established the US Geological Survey (USGS) Astrogeology Science Center.

Once their children had grown up, Carolyn found herself looking for something to avoid 'empty-nest syndrome'. At this time, Gene had been developing a program to find close Earth-approaching asteroids and calculate the probability of an impact with Earth. In need of an extra pair of hands – or in this case eyes – Gene asked Carolyn if she would like to help him look for such objects.

Carolyn accepted Gene's offer, taking up a position as a visiting scientist with the astrogeology branch at the USGS. At the age of 51, while most people are thinking about 'slowing down', Carolyn's astronomical career was only just getting started. Carolyn quickly picked up new techniques, and soon became comfortable with the stereoscope – a piece of equipment that allows for one eye to look at one target and the other at a separate object. Carolyn would carefully examine photographic plates using a stereoscope to view two at a time to identify whether anything 'out of the ordinary' was visible, something that might indicate a possible interplanetary body such as an asteroid or comet. It would take about 13 hours per night to collect images of the night sky, and then countless more hours painstakingly studying them for the slightest change.

Despite the gruelling hours, this work really suited Carolyn and her attention to detail, which she put down to her gender and parental responsibilities: "Motherhood teaches patience for detail and that women tend to look at the finer details more than men."

At her peak, Carolyn's impressive discovery rate was about 100 search hours per comet find. By 1989 Carolyn was a research professor of astronomy at Northern Arizona University, and in 1993 Carolyn and her husband Gene, along with coworker David Levy, rose to fame with the discovery of Comet Shoemaker-Levy 9. The comet had a dramatic demise in 1994 when it bombarded Jupiter with the force of 300 million atomic bombs.

Carolyn's many achievements did not go unrecognised; in 1988 she and Gene received the Rittenhouse Medal. In 1990 she received an honorary doctorate of science from Northern Arizona University, and was presented with the NASA Exceptional Scientific Achievement Medal in 1996. Carolyn's career would likely not have taken this dramatic turn if it had not been for her supportive husband Gene. In turn, Gene might not have progressed very far with his asteroid statistics program and co-discovered Shoemaker-Levy 9 if it had not been for his wife Carolyn. They were the ultimate team.

All About Space

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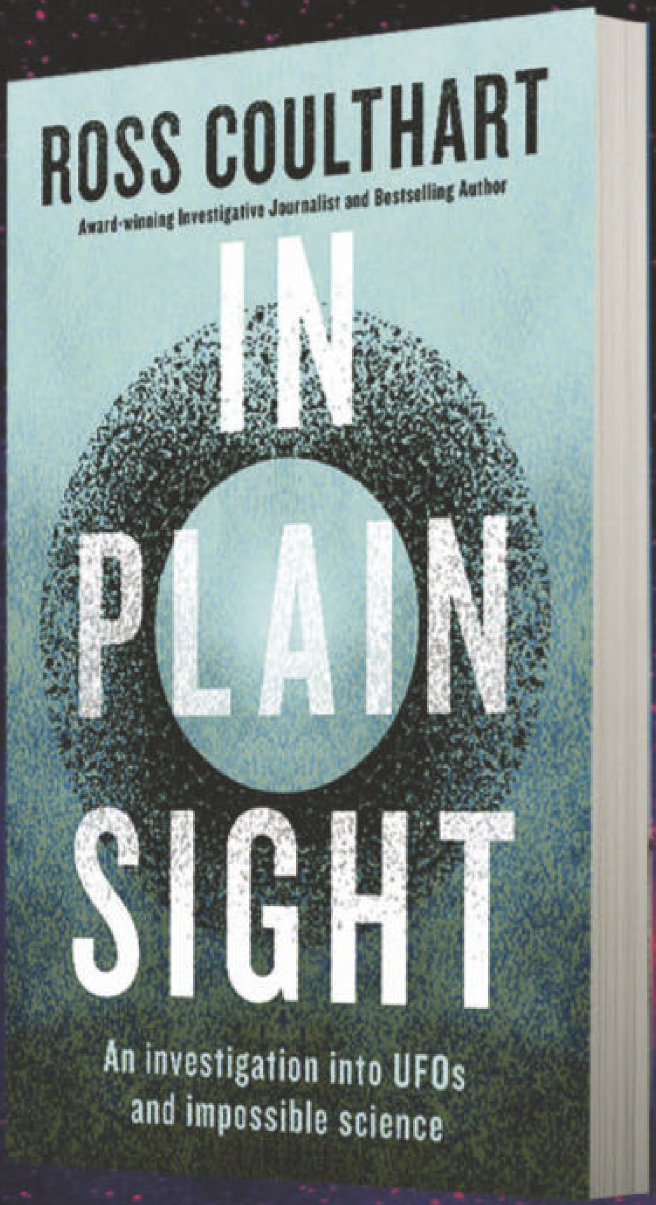
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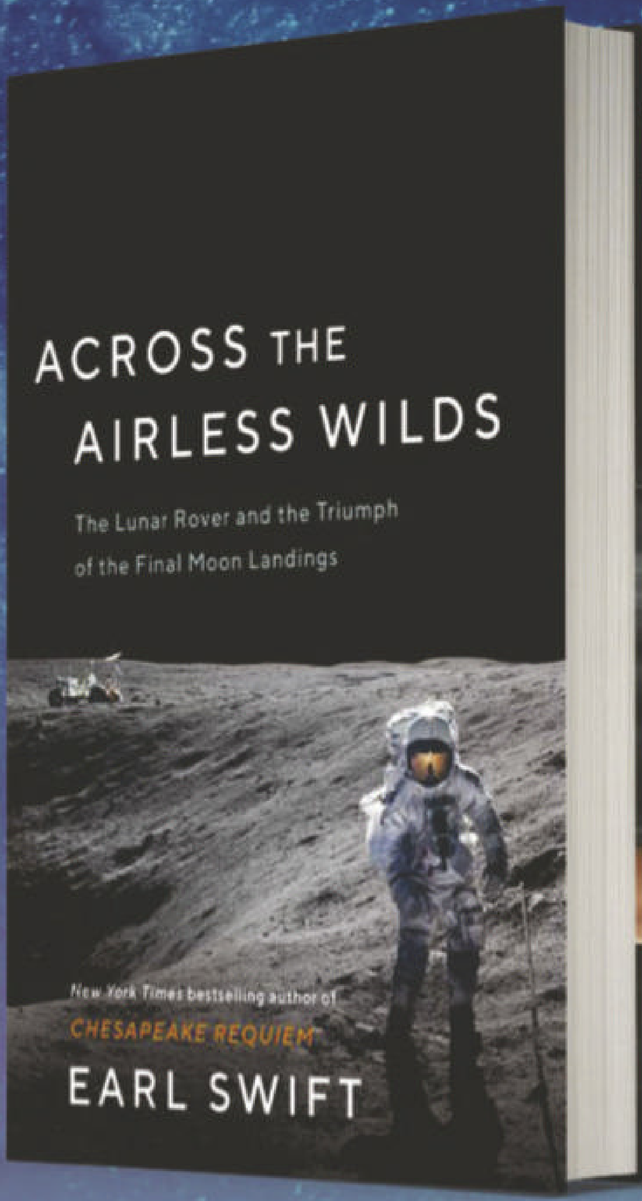
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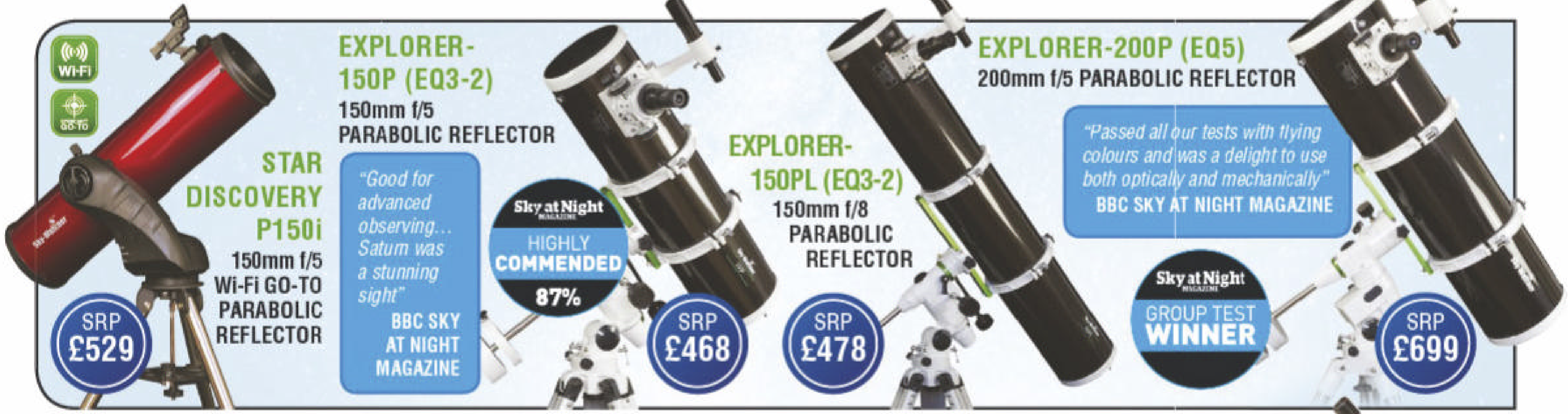

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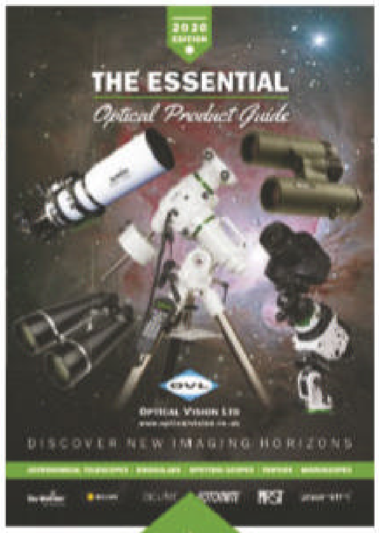
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